POPULATION ECOLOGY OF LEAFHOPPERS (HEMIPTERA : EURYMELIDAE) ON EUCALYPTS AND THEIR ASSOCIATIONS WITH ANTS

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BY

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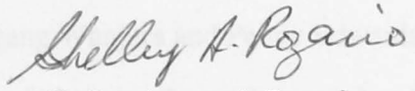
DECLARATION

This thesis does not contain any material which has been submitted for the award of any degree or diploma at any university. This is the candidate's own work and all the sources used have been acknowledged.



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ABSTRACT

This study deals with the biology and field ecology of two species of eurymelid leafhoppers (family Eurymelidae), *Eurymeloides punctata* (Signoret) and *Eurymela distincta* (Signoret). These species feed on eucalypts, are attended by ants and occur in the Southern Tablelands of New South Wales and the Australian Capital Territory. The study was carried out in a eucalypt plantation at 'Millpost', near Bungendore, NSW, where monospecific and mixed species plots of eucalypts have been planted by the Insect and Eucalypt Establishment Project of the Division of Entomology of CSIRO.

At this site, *E. punctata* had three overlapping generations per year and the egg was the main overwintering stage. Most adults moved onto younger eucalypts in adjoining plots when the plants reached about three years of age. *E. distincta* had one distinct generation per year and the adult was the overwintering stage. *E. distincta* occurred on larger trees in the plantation and also on mature eucalypts in the woodland surrounding the plantation. Both species have five nymphal stages; these are described in detail for *E. punctata.* The five nymphal instars of *E. punctata* can be separated by head width, pronotum width, hind tibial length and the development of the wing pads. The sex of nymphs can be recognized from changes in the external genitalia from the third instar onwards.

Eggs of both *E. punctata* and *E. distincta* were parasitised by mymarid wasps, with a different wasp species attacking each eurymelid species. Nymphs of both eurymelid species were also occasionally parasitised by a dryinid wasp (*Anteon* sp.). Egg parasitism was the main cause of mortality in populations of *E. punctata* ; during the period December 1987 to February 1988, 25-98% of the eggs were parasitised. Mortality of eggs due to adverse weather was also recorded. Parasitoids were never observed in early instar nymphs of *E. punctata* but the later instars were

occasionally parasitised. First and second instar nymphs of *E. distincta* apparently were never parasitised while third, fourth and fifth instars were often parasitised. Nymphs, especially early instars, also suffered some mortality from predators and adverse weather.

Adults and nymphs of all populations of *E. punctata* and *E. distincta* were attended by ants of an *Iridomyrmex* species. Eggs of *E. punctata* were also attended by ants, whereas eggs of *E. distincta* were not. Both eurymelids and ants benefited from this association: the ants gained an additional food source, in the form of eurymelid honeydew, while the eurymelids gained protection against predators and parasitoids and had contaminating honeydew removed. Successful ovipositon and survival of eggs and nymphs of both eurymelid species were reduced if ants were excluded. In the first field season (Dec. 1986-July 1987) only two out of six second generation populations of *E. punctata* persisted after removal of ants, and in the second field season (Nov. 1987-June 1988) only one out of six populations (first generation) persisted. Fewer data were available for *E. distincta* but a similar trend was apparent.

Some trees supported populations of scale insects, *Eriococcus* species, in addition to the eurymelids. On trees where there were large numbers of *Eriococcus* , ants were observed to tend the scale insects rather than the eurymelids. Competition for ant attendance may be important for eurymelid survival.

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CHAPTER- ONE

INTRODUCTION

A large superfamily of leafhoppers, the Cicadelloidea, is represented in Australia by three families : Cicadellidae, Membracidae and Eurymelidae (Woodward, Evans and Eastop 1970). The family Eurymelidae is restricted to Australia apart from sparse representation in New Guinea and New Caledonia. The taxon was raised from subfamilial rank to familial status by Evans (1934) and has since been revised by Evans (1966).

Eurymelids are one of the most primitive groups of leafhoppers, and originated in the Australian region (Nielson 1985). They may be easily recognized by the widely flattened face, with ocelli posteriorly adjacent to the diamond-shaped frontoclypeus. The maxillary plates are wide and the transverse suture of the clypeus is strongly developed (Evans 1946).

The family Eurymelidae contains three tribes (Evans 1933, 1966). The species investigated in this study belong to the tribe Eurymelini. Adults of this tribe typically have shiny blue, black or brown tegmina, with or without white or coloured fasciae, although some species exhibit considerable variation in colour pattern. Males have large and broad subgenital plates with a style arising from one of the edges (Evans 1933). The species are all ant-attended and feed solely by sucking the sap of eucalypts on which they live in discrete, mobile groups within the canopy (Evans 1966).

1.1 THE SPECIES OF EURYMELID STUDIED

Two species of Eurymelini, *Eurymeloides punctata* (Signoret) and *Eurymela distincta* (Signoret), were studied with emphasis on the former. These two species occur on eucalypts in the Southern Tablelands. *E. punctata* was the most common and *E. distincta* was the second most common species of eurymelid at the study site. Two other species of eurymelids were recorded but not studied. *Eurymeloides lineata* Signoret occurred on *E. viminalis* , as did *E. punctata* and *E. distincta*. An unidentified species of Ipoini was found only on *E. melliodora* .

1.1.1 *Eurymeloides punctata*

The genus *Eurymeloides* Ashmead was revised by Evans (1966) who considered the principal diagnostic character to be the shape of the aedeagus. Males of *Eurymeloides* have broad subgenital plates with ventral styles. A diagnostic character of secondary importance is the presence of spurs on two adjacent edges of the hind tibiae (Evans 1966).

Eurymeloides punctata is a widespread and morphologically variable species that has been studied recently by Stevens (1985). The body of the adult is 7.9 to 8.4 mm long (Stevens 1985). The head is black to brown and variously mottled with cream colour. The tegmina are black to mid-brown, often with irregular white fasciae and sometimes a third, middle fascia is present. This species occurs in many parts of Australia and is also known from New Guinea (Evans 1966; Stevens 1985). Stevens redescribed the adult male and female of *E. punctata* and listed the distributions and host-plant associations of all species of *Eurymeloides* . The known food-plants of *E. punctata* at the time of Stevens' (1985) publication were *Eucalyptus blakelyi* , *E. dalrympleana* , *E. nicholii* and *E. pauciflora.*

1.1.2 *Eurymela distincta*

The genus *Eurymela* Le Pelletier and Serville was revised by Evans (1966) and five species were described. These are wedge-shaped brown or black insects sometimes with a metallic sheen and are 6 to 14 mm in length. The hind tibiae have a single prominent spur on the ventral anterior edge, and a smaller spur and a few small spines on the inner posterior and dorsal anterior edges. The male genitalia have large boat-shaped subgenital plates (Evans 1966).

The adult of *E. distincta* is 10-14 mm long, bluish or purplish-black in colour and usually has one, two or three fasciae on each tegmen. The pronotum and scutellum are black and the proximal ends of the legs and ventral surface of the thorax and abdomen are scarlet. This species occurs only in New South Wales, Victoria and Tasmania (Evans 1966). *Eurymela distincta* has been recorded from *Eucalyptus bridgesiana* and *E. botryoides* (Evans 1931; Lindsay and Marshall 1980).

1.2 THE STUDY SITE

The study on eurymelid ecology was undertaken at the main experimental site of the Insect and Eucalypt Establishment Project of the Division of Entomology, CSIRO. This site is at 'Millpost', a property near Bungendore, 22 km east of Canberra (map ref. 142°22'E, 35°18'S). The altitude is 840m. The plantation (Fig. 1.1) is established in a cleared improved pasture surrounded by partially cleared savannah woodland dominated by *E. melliodora*, *E. mannifera*, *E. rubida* , *E. bridgesiana* and *E. pauciflora.*

The CSIRO project was established to study insect herbivory and its effect on the growth and survival of eucalypts planted on pastures of the Southern Tablelands. Eight species of *Eucalyptus* L'Hérit, with different growth form and leaf shape were

selected for planting. Species native to the tablelands and adjacent ranges of NSW were selected. These were planted at approximately six months of age between autumn and spring in 1984, 1985 and 1987 in replicated blocks (Figs 1.2, 1.3 and 1.4). A block was either of a single species or of mixed species of woodlot types (4 species) and shelterbelt types (4 species). Each block consisted of 113 trees (8x8 grid + 7x7 intercalated), of which 64 were 'permanent' and 49 were 'removal' trees. Four experimental (exposed to insects) and four control (insect free through the use of insecticide) blocks were planted in 1984. The distance between the control and experimental blocks at the study site was 100 metres. The size of each block was 24 x 24 metres and the distance between the blocks was 10 metres. The distance between the trees in a block was 3 metres. Wood chips were placed around the bases of all the trees at the time of planting (except in 1984) in order to control weeds and maintain soil moisture. The trees were watered and fertilized when planted but not thereafter. The following species were selected and planted at the Millpost study site in 1984-

(i) Woodlot types

1. *E. blakelyi* Maiden,
2. *E. melliodora* A. Cunn. ex Schauer,
3. *E. pauciflora* Sieber ex Sprengel
4. *E. sideroxylon* A. Cunn. ex Wolls

(ii) Shelterbelt types

1. *E. globulus* subsp. *bicostata* (Maiden *et al*) Kirkpatr.
2. *E. caliginosa* Blakely *et* Mckie
3. *E. macarthurii* Deane *et* Maiden
4. *E. viminalis* Labill.

High mortality occurred among four of the species (including *E. globulus* subsp. *bicostata*) due to extreme frosts and these were replaced with more frost tolerant species for the plantings of 1985 and 1987. The replacements were: *E. bridgesiana*

Fig. 1.1

Millpost, the study site,looking towards the west.

Fig. 1.2

Block A; a block of *E. viminalis* planted in 1984 at Millpost. Photograph taken in February 1988.

Fig. 1.3

Block B; a block of *E. viminalis* planted in 1985 at Millpost. Photograph taken in February 1988.

Fig. 1.4

Block C; a block of *E. viminalis*, *E. macarthurii*, *E. aggregata* and *E. camphora* planted in 1987 at Millpost. photograph taken in February 1988.

R.T. Bak. for *E. blakelyi*, *E. mannifera* Mudie for *E. sideroxylon* and *E. aggregata* Deane and Maiden for *E. caliginosa*. *E. camphora* R. T. Bak. was planted to replace *E. globulus* subsp. *bicostata*, but three months later in 1985 than the other species.

The numbering system of the trees in a block is illustrated in Figure 1.5. Trees used in the eurymelid study are identified by this numbering system (see Appendix A1 and B1).

The overall growth rate of the trees in the experimental and the control blocks are compared by removing some of the trees (removal trees) annually and measuring the biomass production. Colonisation and distribution of insects on all experimental trees is assessed by a group of observers at regular intervals. The population ecology (survival rate and possible causes of mortality) of populations of various insect species is studied by scientists from the CSIRO. The research on eurymelids described here therefore forms part of a larger study of the ecology of insects and eucalypts at 'Millpost'.

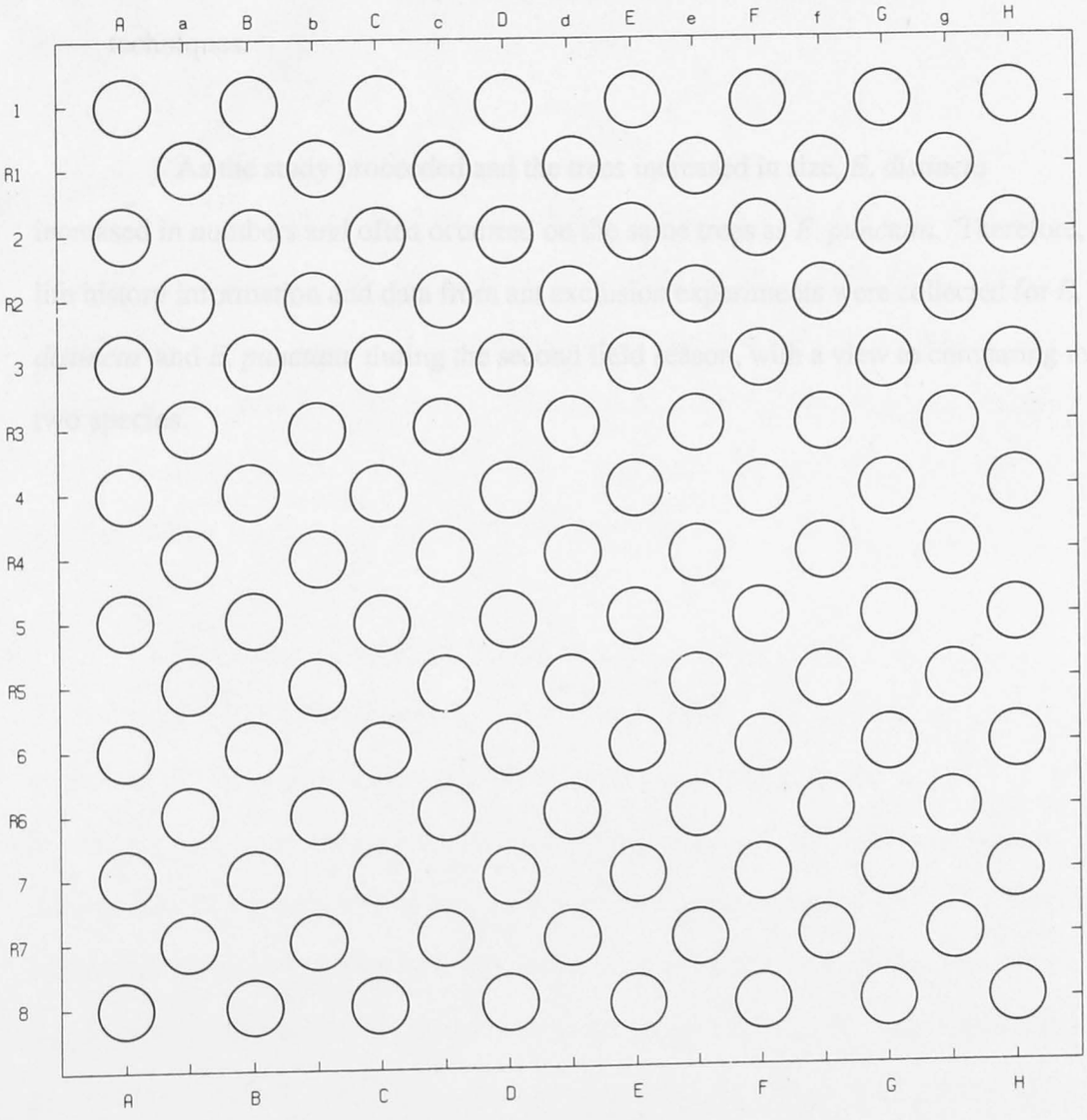
1.3 OBJECTIVES OF THE STUDY

Many aspects of eurymelid life history, including the number of generations per year, the effects of ant attendance, and mortality factors operating on populations, have yet to be determined for any species. Thus my research objectives were to describe the field biology of a eurymelid species. *Eurymeloides punctata* was of particular interest because it colonises young eucalypts in plantations, often in large numbers, with unknown effect on growth and survival of those plants. I set out to:

1. describe the immature stages of *E. punctata* using morphometric characters to enable nymphs to be categorized, where possible, according to sex and instar,

Fig. 1.5

Design of a block at Millpost. Trees are represented by circles and are numbered as 1A, 1B.....1H ('permanent' trees) and R1A, R1B.....R1G ('removal' trees) in a block.


A a B b C c D d E e F f G g H
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2
R2
3
R3
4
R4
5
R5
6
R6
7
R7
8
A B C D E F G H

2. study the phenology of *E. punctata* and determine its range of host plants,

3. identify any predators and parasitoids attacking *E. punctata* to measure impact of these enemies on eurymelid populations,

4. describe population processes by constructing life-tables, and

5. study the relationship between ants and *E. punctata* using ant exclusion techniques.

As the study proceeded and the trees increased in size, *E. distincta* increased in numbers and often occurred on the same trees as *E. punctata.* Therefore, life history information and data from ant exclusion experiments were collected for *E. distincta* and *E. punctata* during the second field season, with a view to comparing the two species.

CHAPTER - TWO

DESCRIPTION OF THE FIVE NYMPHAL INSTARS OF *EURYMELOIDES PUNCTATA* (SIGNORET)

2.1 INTRODUCTION

The nymphs of *E. punctata* are gregarious in all developmental stages, and all stages including adults, may be found in the same aggregations. Therefore, it is necessary to be able to identify the developmental stages in order to study their biology and population ecology. The nymphs of eurymelid species have not previously been studied in detail. This chapter describes the five nymphal instars of *E. punctata* and provides a key for their easy recognition and sexing.

Various authors (Williams 1957; Rothschild 1964; Vilbaste 1968, 1982; Kathirithamby 1977; Fletcher 1979, 1981; Wilson 1983) have used the relative growth of the wing pads, changes in body length, head width, femur length, chaetotaxy of the abdomen, characters of the hind tibiae and tarsi, and number and arrangement of the sensory pits on the body surface to distinguish the nymphal instars of auchenorrhynchan Homoptera. However, in nymphs of all Cicadelloidea sensory pits are absent, the chaetotaxy of the body and legs does not provide useful characters to identify the instars, and the tarsi have two segments on all legs in all instars (M.J. Fletcher, pers. comm.).

Rudiments of external genitalia are visible in auchenorrynchan nymphs as they pass through the five nymphal stages prior to the final moult (adult). It is usually possible to sex at least the older nymphs. In Cicadellidae the sexes can be separated at

the third instar when the external genitalia are visible (Kathirithamby 1974, 1977; Wilson 1983). In female nymphs of Cicadellidae, two pairs of outgrowths are present and visible in the third instar while three pairs of outgrowths are present but only one pair is visible in fourth and fifth instars (Kathirithamby 1974, 1977; Wilson 1983). In nymphal Delphacidae genital appendages also appear in the third instar, when rudiments of the ovipositor can be seen in females (Vilbaste 1968; Kathrithamby 1981), but nymphs of *Conomelus anceps* (Germar) (Delphacidae) have been sexed only in the fifth instar by the structure of the terminal abdominal segments (Rothschild 1964). Wilson (1983) also found satisfactory and completely reliable separation of the sexes only in the fifth instar of the delphacids *Nilaparvata lugens* (Stål), *Sogatella furcifera* (Horvath), *Sogatodes pusanus* (Distant), and *Laodelphax striatellus* (Fallen). No apparent external differentiation of sexes has been found in fifth instar nymphs of the fulgoroids *Kallitambinia australis* Muir (Tropiduchidae), *Scolypopa australis* (Walker) (Ricaniidae) (Fletcher 1979, 1981) and *Nisia nervosa* (Motsch) (Meenoplidae) (Wilson 1983). The present study included an investigation into the stage at which the sex of the nymphs of *E. punctata* could be first detected.

2.2 METHODS

Nymphs of *E. punctata* were collected from aggregations with adults at three different sites: 'Millpost', 22km east of Canberra, N.S.W., 'Gundowringa', 14km south east of Crookwell near Goulburn, N.S.W., and the CSIRO grounds, Black Mountain, Canberra, ACT. Specimens from Millpost and Gundowringa were collected on *Eucalyptus viminalis* Labill. and from Canberra on *E. mannifera* Mudie. Specimens were collected from Millpost on 11 February and 2 March 1987, from Gundowringa on 17 November 1987 and from Black Mountain on 28 April and 28 October 1987. Nymphs and adults were collected and preserved in 70% ethanol. Ethanol preservation caused swelling of some nymphs, especially those about to moult, so these were excluded from measurement.

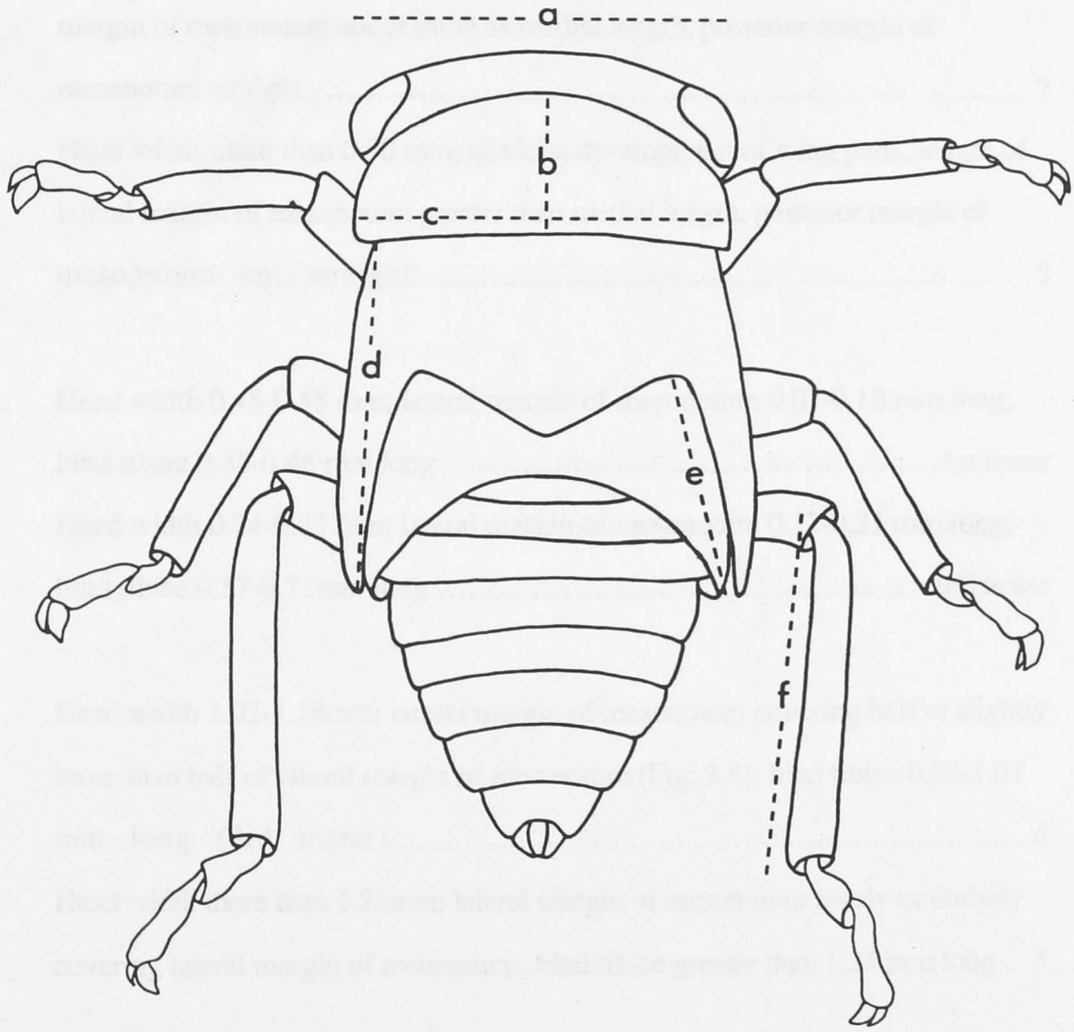
Specimens were sorted into instar groups on the basis of body size. Individuals were placed with the dorsum upwards and measured using an eye piece graticule in a Wild M3 dissecting microscope. Sixteen individuals for the first, 21 for the second, 20 for the third, 23 for the fourth and 27 for the fifth instar were measured from Millpost. Five individuals of each instar were measured from Gundowringa. Five individuals for the first, second and third instar and 13 for the fourth and fifth instar were measured from the Black Mountain site. The characters (Fig. 2.1) used were: head width, length of the lateral edge of the mesonotum, pronotum length, pronotum width, body length and hind tibial length for all instars; in addition, the length of the inner margin of the wing pad was measured for fourth and fifth instars. The length of the antennal arista was measured for only 5 individuals of each instar collected at Millpost. Body colour patterns of the five nymphal instars were also assessed for the descriptions. In the descriptions all measurements are recorded as the range in millimetres with the mean and standard deviation in parentheses.

The sexes were determined by examination under a dissecting microscope and the external genitalia of third, fourth and fifth instar nymphs were photographed using a Jeol JSM 35C scanning electron microscope.

All specimens from which measurements were taken have been deposited in the Australian National Insect Collection (ANIC), CSIRO, Canberra. Voucher specimens of adult males and females also have been deposited in the ANIC.

Fig. 2.1

A fifth instar nymph of *E. punctata* showing the different parts of the body measured and used in the description. a=head width; b=pronotum length; c=pronotum width; d=length of lateral edge of mesonotum; e=inner margin of mesonotal wing pad; f=length of hind tibiae.



2.1

2.3 KEY TO THE FIVE NYMPHAL INSTARS AND SEX OF THE 3RD, 4TH AND 5TH INSTARS OF *EURYMELOIDES PUNCTATA*

1. Head width less than 0.90 mm; no development of wing pads, length of lateral margin of mesonotum about same as medial length, posterior margin of mesonotum straight 2

- Head width more than 0.90 mm; obvious development of wing pads, length of lateral margin of mesonotum greater than medial length, posterior margin of mesonotum not straight 3

2. Head width 0.48-0.58 mm; lateral margin of mesonotum 0.07-0.12 mm long; hind tibiae 0.38-0.46 mm long ..... 1st instar

- Head width 0.74-0.83 mm; lateral margin of mesonotum 0.12-0.21 mm long; hind tibiae 0.57-0.71mm long ..... 2nd instar

3. Head width 1.02-1.18mm; lateral margin of mesonotum covering half or slightly more than half of lateral margin of metanotum (Fig. 2.4); hind tibiae 0.93-1.07 mm long (3rd instar)..... 4

- Head width more than 1.25mm; lateral margin of mesonotum nearly or entirely covering lateral margin of metanotum; hind tibiae greater than 1.25 mm long .. 5

4. Broad triangular subgenital plate arising from sternite IX, plate with short median apical slit (Fig. 2.7) ..... 3rd instar male

- Paired outgrowths (1st and 2nd gonapophyses in adult) arising posteriorly from sternites VIII and IX (Fig. 2.8) .....
..... 3rd instar female

5. Head width 1.51-1.72 mm; lateral margin of mesonotum 0.55-0.85 mm long, nearly covering lateral margin of metanotum (Fig. 2.5); hind tibiae 1.33-1.58 mm in length (4th instar) 6

- Head width 2.06-2.42 mm; lateral margin of mesonotum 1.51-2.12 mm long, entirely covering lateral margin of metanotum (Fig. 2.6); hind tibiae 1.82-2.30 mm in length (5th instar) 7

6. Broad triangular subgenital plate with short apical slit (Fig. 2.9) .... 4th instar male

- Outgrowths from sternite VIII extending over those from sternite IX (Fig. 2.10) ..... 4th instar female

7. Broad triangular subgenital plate with medial division for about half its length (Fig.2.11)..... 5th instar male

- Outgrowths from sternite VIII forming an elongate, triangular plate with medial division reaching almost to base (Fig. 2.12) .... 5th instar female

2.4 DESCRIPTION OF NYMPHAL INSTARS

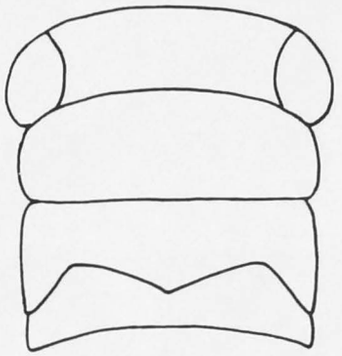
2.4.1 First instar (Figs 2.2, 2.13)

Body uniformly brown to dark brown dorsally (Fig. 2.13); coxae brown; abdominal sternites cream-coloured, last 8 with light brown markings medially. Body length 0.83-1.17 (0.98 $\pm$ 0.08) mm. Body setose.

Head width across eyes 0.48-0.58 (0.54 $\pm$ 0.02) mm. Vertex with sinuous posterior margin hidden by pronotum; rounded anteriorly when viewed from above. Rostrum reaching distal end of hind coxae. Antennal arista length 0.21-0.24 (0.22 $\pm$ 0.01) mm.

Figs 2.2 - 2.6

Head and thorax of nymphs of *E. punctata* . (2.2) first instar; (2.3) second instar; (2.4) third instar; (2.5) fourth instar; (2.6) fifth instar.



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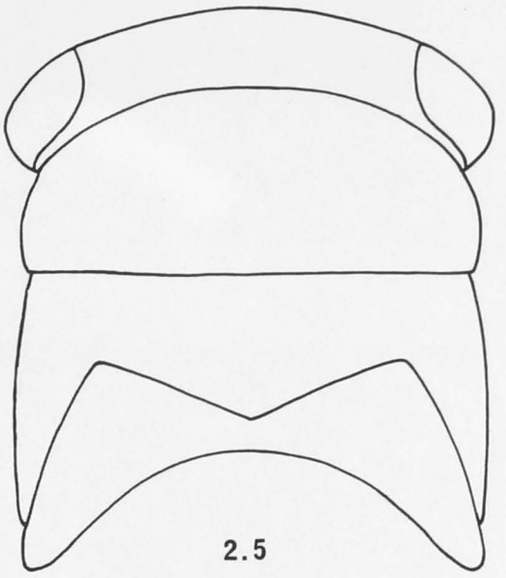

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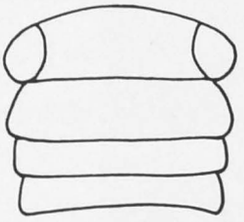

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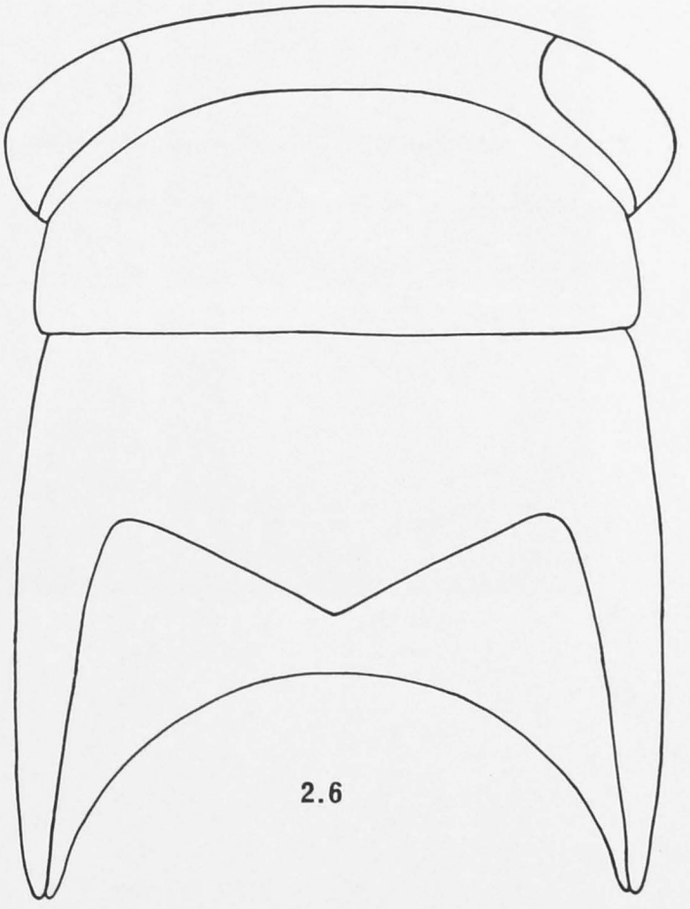
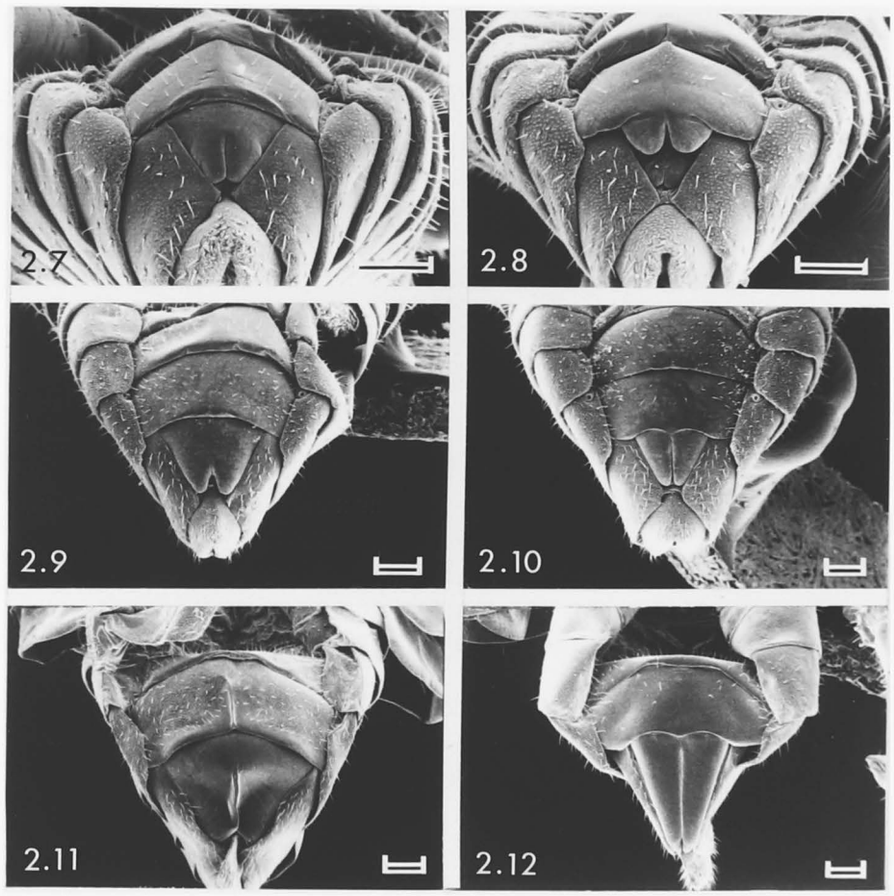


2.6

2.2

Figs 2.7- 2.12

Scanning electron micrographs showing development of external genitalia in male and female nymphs of *E. punctata*. (2.7) third instar male; (2.8) third instar female; (2.9) fourth instar male; (2.10) fourth instar female; (2.11) fifth instar male; (2.12) fifth instar female. All scale lines= 0.1mm.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Figs 2.13 - 2.18

Body colour patterns in first to fifth instar nymphs of *E. punctata* . (2.13) first instar; (2.14) second instar; (2.15) third instar; (2.16) fourth instar; (2.17) fifth instar (darker form); (2.18) fifth instar (lighter form).

2.13

2.14

2.15

2.16

2.17

2.18

2.4.3 Third instar (Figs 2.4, 2.7, 2.8, 2.15)

Body colour dark brown with some amber or cream coloured markings; genae cream coloured anteriorly and light brown posteriorly; pro-, meso- and metanota with amber or cream coloured posterolateral margins, usually pronotum darker than meso- and metanota; coxae cream coloured; abdominal tergites dark brown with cream coloured posterior margins, last 4 sternites always dark brown (Fig. 2.15). Body length 1.69-2.50 (2.03 ± 0.15) mm. Body setose with more robust setae laterally than dorsally.

Head width across eyes 1.02-1.18 (1.10 ± 0.04) mm. Vertex with sinuous posterior margin hidden by pronotum; anterior margin straighter when viewed from above than in first and second instar. Rostrum reaching distal end of mid coxae. Antennal arista length 0.36-0.40 (0.38 ± 0.02) mm.

Pronotum length in midline 0.33-0.40 (0.36 ± 0.02) mm, width 0.95-1.10 (1.02 ± 0.04) mm; anterior margin slightly convex. Length of lateral margin of mesonotum 0.27-0.36 (0.32 ± 0.03) mm, greater than medial length, and covering at least 1/2 of lateral margin of metanotum (Fig. 2.4); posterior margin of mesonotum V-shaped . Metanotum much longer laterally than medially, nearly covering 2nd visible abdominal segment laterally; posterior margin widely excavated. Tibiae cylindrical; hind tibial length 0.93-1.07 (1.00 ± 0.04) mm. First tarsal segment about 1/2 length of 2nd segment.

Abdomen with length about same as width; rudiments of external genitalia visible. Male: rudiment of broad subgenital plate arising posteriorly from sternite IX (Fig. 2.7). Female: 2 pairs of outgrowths arising posteriorly from sternites VIII and IX (1st and 2nd gonapophyses in adult) (Fig. 2.8).

2.4.4 Fourth instar (Figs 2.5, 2.9, 2.10, 2.16)

Body colour dark brown with amber and cream coloured markings; head mottled with dark brown and amber except for cream coloured genae; thorax mottled with amber and dark brown, anterior and posterior margins of pronotum and posterior

margins of meso- and metanota cream coloured; coxae cream coloured; abdominal tergites dark brown sometimes mottled with a little amber, posterior margins cream coloured, last 4 sternites always dark brown (Fig. 2.16). Body length 2.48-3.58 (3.00 ± 0.21) mm. Body almost glabrous, setae of lateral margins more robust than dorsal setae.

Head width across eyes 1.51-1.72 (1.61 ± 0.05) mm. Vertex with sinuous posterior margin hidden by pronotum; rounded anteriorly when viewed from above. Rostrum reaching base of mid coxae. Antennal arista length 0.43-0.48 (0.45 ± 0.02) mm.

Pronotum length in midline 0.48-0.61 (0.56 ± 0.03) mm, width 1.33-1.58 (1.45 ± 0.05) mm; anterior margin convex. Length of lateral margin of mesonotum 0.55-0.85 (0.72 ± 0.07) mm, distinctly greater than medial length and almost entirely covering lateral margin of metanotum (Fig. 2.5); length of inner margin of mesonotal wing pad 0.30-0.55 (0.43 ± 0.06) mm; posterior margin of mesonotum V-shaped. Metanotum covering 2nd visible abdominal segment laterally; posterior margin excavated. Fore and mid tibiae cylindrical; hind tibiae slightly quadrilateral, length 1.33-1.58 (1.48 ± 0.06) mm. First segment 1/2 length of 2nd segment; 2nd segment of hind tarsi slightly narrowed at midlength.

Abdomen with length about same as width. Male: subgenital plate broad with short apical slit (Fig. 2.9). Female: paired outgrowths from sternite VIII extending over those from sternite IX; apical slit of external genitalia extending almost to base (Fig. 2.10).

2.4.5 **Fifth instar** (Figs 2.6, 2.11, 2.12, 2.17, 2.18)

Body colour mostly amber with dark or light brown markings; head amber with light or sometimes with dark brown markings except cream coloured genae; thorax mostly amber with dark brown markings on anterior and posterior margins of nota, lateral margins of meso- and metanota lighter in colour than rest of thorax; coxae cream coloured. abdominal tergites mostly amber with dark brown and cream coloured

posterior margins, 7th visible tergite usually wholly amber in colour, last 2 tergites mostly dark brown with a little amber, last 4 sternites always dark brown (Figs 2.17, 2.18). Body length 3.64-5.64 (4.50 ± 0.39) mm. Body almost glabrous, but a few setae on lateral margins of head and pronotum, setae of pronotum more robust than others.

Head width across eyes 2.06-2.42 (2.23 ± 0.09) mm. Vertex with excavated posterior margin hidden by pronotum; narrow when viewed from above (Fig. 2.6). Rostrum reaching base of mid coxae. Arista length 0.52-0.61 (0.56 ± 0.03) mm.

Pronotum length in midline 0.73-0.91 (0.82 ± 0.05) mm, width 1.88-2.27 (2.02 ± 0.09) mm; anterior margin convex. Length of lateral margin of mesonotum 1.51-2.12 (1.77 ± 0.13) mm, at least twice medial length, extending to distal extremity of lateral margins of metanotum (Fig. 2.6); length of inner margin of mesonotal wing pad 0.97-1.51 (1.22 ± 0.14) mm; posterior margin of mesonotum V-shaped. Lateral margins of meso- and metanotum nearly covering 3rd visible abdominal segment laterally. Metanotum excavated posteriorly. Fore and mid tibiae cylindrical; hind tibiae quadrilateral, length 1.82-2.30 (2.09 ± 0.09) mm. First tarsal segment 1/2 length of 2nd segment; 2nd segment of fore, mid and hind tarsi narrowed at midlength.

Abdomen with length about same as width. External genitalia well developed. Male: subgenital plate broad with short apical slit (Fig. 2.11). Female: with elongate, triangular plate with long medial slit from apex almost to base (Fig. 2.12)

2.5 SUMMARY OF RESULTS AND DISCUSSION

To study the biology and field ecology of any species it is neccessary to be able to recognize the individuals in their developmental stages. This study shows that the instar of nymphs of *E. punctata* can be determined by head width, pronotum width, development of wing pads and hind tibial length. Measurements of these characters do not overlap between instars, in contrast to body length which varies considerably

within some instars and shows some overlap between instars (Fig. 2.19). Figure 2.20 shows the discrete ranges of head width in different instars.

First and second instar nymphs of *E. punctata* are usually uniformly brown to dark brown (Figs 2.13, 2.14). The colour pattern of the body of nymphs of *E. punctata* can vary in the same instar even at the same locality and time (Figs 2.15-2.18). Newly hatched and newly moulted nymphs are always cream coloured, however, they darken in about twenty minutes.

Colour patterns have been used to identify the nymphs of some Auchenorrhyncha and variation in colour patterns in some species has also been recorded (Vilbaste 1982; Wilson 1983). In nymphs of *E. punctata,* variation in body colour is most apparent in the third, fourth and fifth instars of both sexes. The areas of amber, dark brown and cream colour on the body can vary in size and shade to make nymphs appear darker or lighter (Figs 2.17, 2.18). Although adults were not described in this study, it was found that in males the ventral side of the abdomen was always darker in colour than in females. This colour difference between males and females was not mentioned in previous work by Evans (1966) or Stevens (1985).

In conclusion, for *E. punctata* head width in the early instars and body colour and head width in the third to fifth instar were found to be the most useful characters to recognize nymphal instars in the field. The characters used to separate the instars did not vary with time or locality.

Fig. 2.19

Ranges of body lengths for first to fifth instar nymphs of *E. punctata*.

Numbers of individuals measured

first instar= **26**

second instar= **31**

third instar= **30**

fourth instar=**41**

fifth instar= **45**

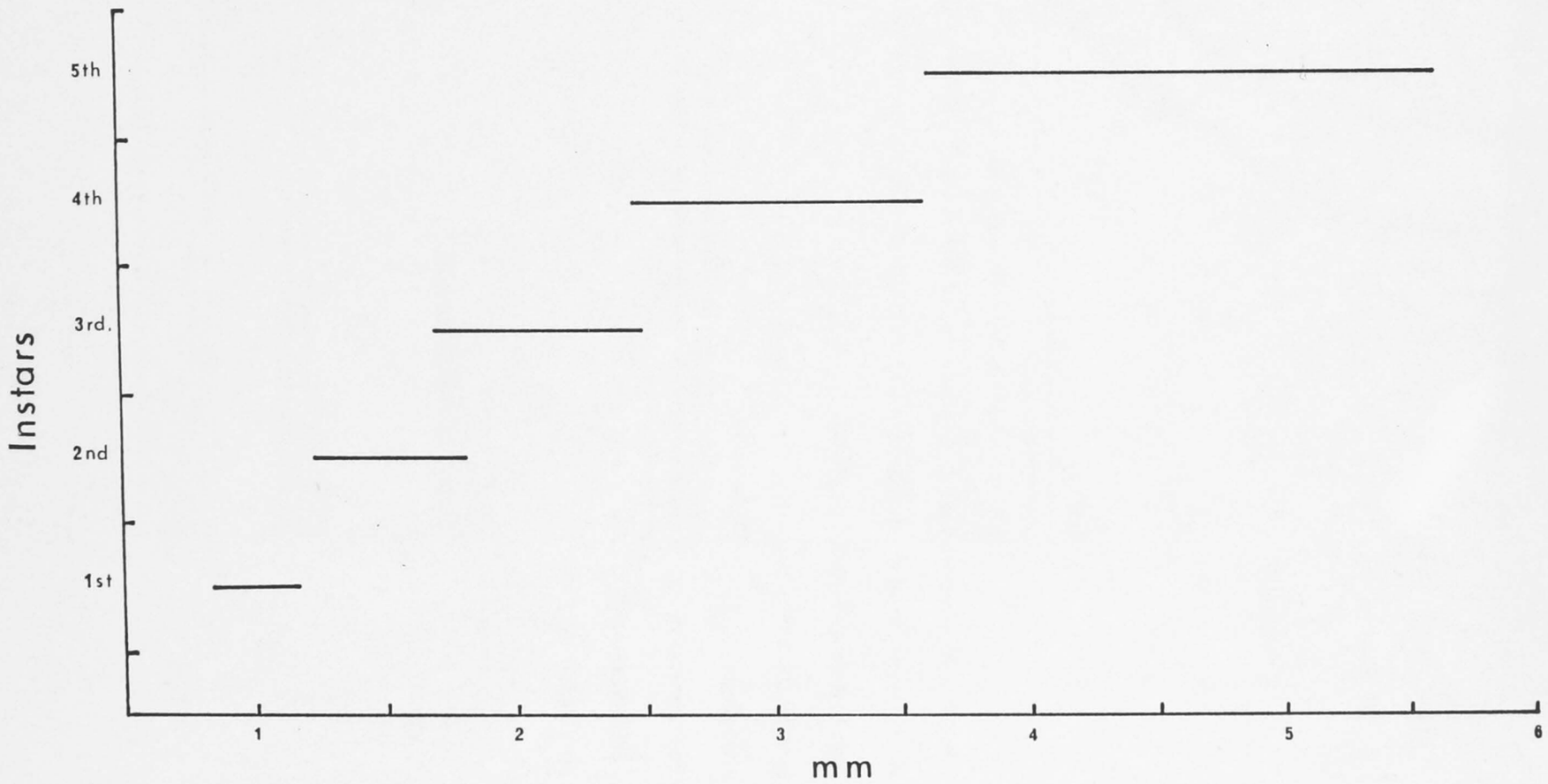

Instars
5th
4th
3rd.
2nd
1st
1
2
3
4
5
6
mm

Fig. 2.20

Frequancy of head width in *E. punctata* in relation to developmental stage (from first to fifth instar). Head width measurements were grouped in increament of .02 mm.

Numbers of individuals measured

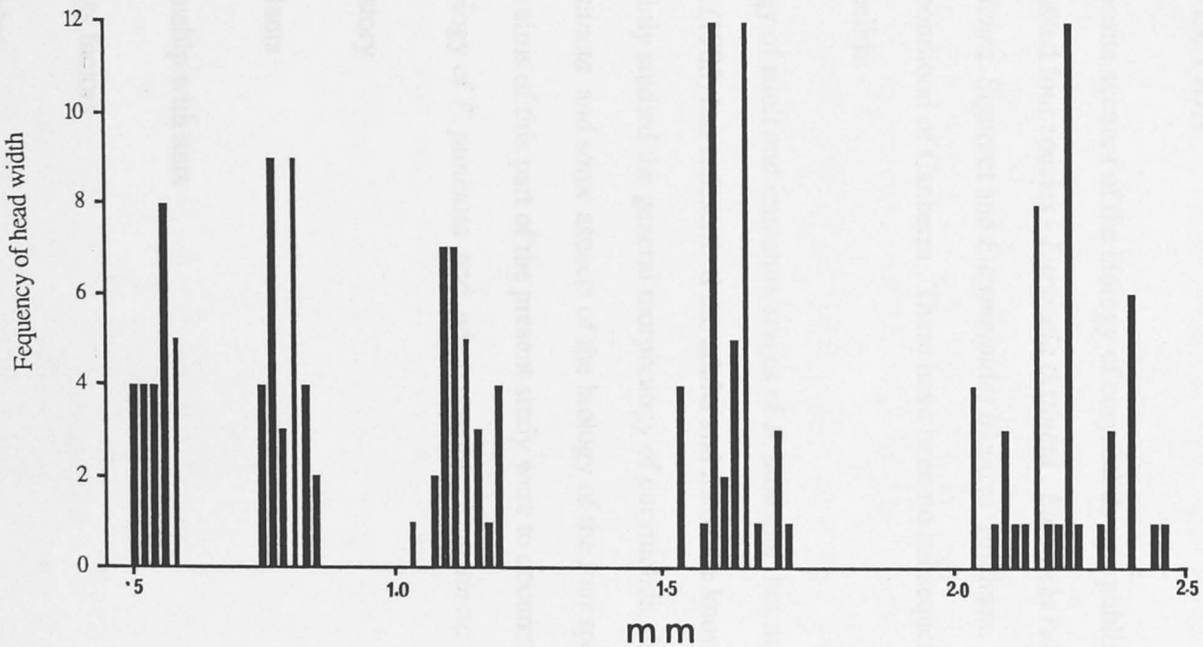
first instar= **26**

second instar= **31**

third instar= **30**

fourth instar= **41**

fifth instar= **45**


Fequency of head width
12
10
8
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4
2
0
·5
1·0
1·5
2·0
2·5
m m

CHAPTER - THREE

GENERAL BIOLOGY OF *EURYMELOIDES PUNCTATA* AND *EURYMELA DISTINCTA*

3.1 INTRODUCTION

A composite account of the biology of eurymelids was published by Evans (1931) who discussed four species - *Eurymela distincta* , *Eurymela rubrovittata* A. S., *Eurymeloides pulchra* Signoret and *Eurymeloides bicincta* Erichson. His study site was in the neighbourhood of Canberra. There have been no subsequent studies on the biology of eurymelids.

The biology of adult and immature stages of *E. punctata* has not been studied, although Stevens (1985) has redescribed the adults and listed the known host plants. Evans (1931) mainly studied the general morphology of eurymelids, the internal anatomy of *E. distincta* and some aspects of the biology of the four species mentioned above. The main aims of this part of the present study were to document the following aspects of the biology of *E. punctata* and, when possible, *E. distincta* :

1. Life history

2. Host plants

3. Relationship with ants

4. Mortality factors

5. Life-tables.

A life-table is mainly a device for representing the survival rate of a group of individuals. Age-specific or horizontal (cohort) life-tables work very well for short-lived organisms such as leafhoppers. Age-specific life-tables can be made for univoltine leafhoppers by sampling at successive times in the field (Southwood,1978; Madden, 1985). Some studies (Hokyo and Kuno 1977; Waloff and Thompson 1980) have involved the construction of life-tables for leafhoppers using field data from samples collected by sweepnet and D-vac suction sampler. However, multivoltine leafhoppers usually have overlapping generations, and often controlled studies are necessary to construct the age-specific life-tables (Southwood,1978; Madden, 1985). An alternative approach for producing life-tables involves estimating the mean number of individuals present at each instar (Farrow 1979). This can be achieved by summing the numbers present at each successive count and dividing the cumulative total by a factor representing the duration of the instar. Manly (1974) developed an analytical method for estimating the number of individuals entering each stage, the mean duration of each stage and the daily survival rate of each stage. His method assumes that there is a constant death rate for all stages and that insects enter each stage according to a normal distribution. Waloff and Thompson (1980) used Manly's method to construct life-tables for six leafhopper species living on grasses.

Life-tables have not previously been prepared for eurymelid populations. In this study an attempt was made to determine the total number of individuals of *E. punctata* entering each stage with the intention of constructing life-tables.

3.2 METHODS

Eurymelids were studied in three adjacent blocks of shelterbelt eucalypts at Millpost. These were two monospecific blocks of *E. viminalis* and a block of mixed species. A monospecific block (planted in 1984, block A) was chosen for the study in 1986, since at that time *E. punctata* was found only on *E. viminalis* and mostly in this block. From early 1987 *E. punctata* was abundant in another monospecific block (planted in 1985, block B). In Autumn, 1987 a block of mixed species (block C) was planted between blocks A and B. In addition to these three blocks, other experimental blocks at the site were also observed at intervals in order to record host plants and abundance of eurymelids. This study commenced in December 1986 and all observations were made over two field seasons. During the first field season (December 1986 to July 1987) *E. punctata* was studied in detail. During the second field season (November 1987 to June 1988), there were increased numbers of the second most common species of eurymelid, *Eurymela distincta* , and therefore both species were studied. Additional observations were made in November 1988 to determine the host-plant species preferred by *E. punctata.*

Observations were made every week. Populations (a population refers to the total number of individuals on a single tree) of *E. punctata* were monitored on 12 trees over two field seasons and of *E. distincta* on six trees in the second field season and the number of individuals at each stage of development were estimated by direct counting. The characters used to identify the nymphs in the field were body colour and head width (Chapter 2). The numbers of egg slits made by females on the trees were recorded on each occasion in order to estimate the numbers of eggs. The presence of parasitoids and predators and the incidence of rainfall and cold weather events were recorded. Data on weather were obtained from the CSIRO meteorological station at the experimental site.

Some observations were made at the CSIRO site on Black Mountain. At this site, bark with egg slits of *E. punctata* was collected from *E. viminalis*, and general

observations were made on *E. punctata* on ornamental trees (*E. mannifera*), and on*E. distincta* under the bark of mature eucalypts in winter.

3.2.1 Marking adults

Adults were marked in an attempt to ascertain longevity, mobility and fecundity of females. Adults were very difficult to capture and mark because they evaded hands or collecting equipment when approached and they were easily damaged during handling. Furthermore, their natural behaviour appeared to be disrupted after handling and often they would not resettle on the branch.

Adults were less active at night and therefore 46 out of approximately 70 adults on four trees of *E. viminalis* on block B were captured, during the evening of 9 March 1987. Adults were marked with coloured typing liquid (White-Out®) and released on the same trees. Different colours (white, pink, blue and yellow) were used for adults on each tree. Marked individuals were observed for 24 days (once or twice a week) by counting the marked adults. Neighbouring trees in the block were also checked for marked adults.

3.2.2 Rearing of *E. punctata*

Laboratory and glasshouse rearing was attempted to determine the fecundity of females and the longevity of adults. Twenty nymphs in fifth instar were collected from *E. viminalis* at Millpost on 8 January 1987 and released onto potted saplings of young *E. viminalis* in a glasshouse at the Department of Zoology at the Australian National University. The temperature in the glasshouse ranged from 19°C to 32°C. The adults raised from these nymphs were transferred onto five different saplings. One male and one female were transferred onto each plant and plants were covered with perspex cylinders with mesh tops. Observations were made daily until all adults had died. The

same technique was repeated twice more in January and February 1987 using two variations: (i) mesh bags were used instead of cylinders,to reduce the humidity, and (ii) groups of adults were used instead of pairs. In a fourth trial, four females and two males were collected at Millpost on 19 February 1987, released onto potted sapling in the glasshouse and covered with a mesh bag. Observations were made until the adults died.

Rearing of *E. punctata* was attempted again in January 1988 in a constant temperature room (day temp. 27°C and night temp. 19°C) in the Division of Entomology, CSIRO. Three groups of fifth instar nymphs consisting of 15, 20 and 25 individuals were collected at Millpost from *E. viminalis* and used for this rearing trial. The numbers of new adults were recorded on every second day until all the nymphs had become adults, and these were observed about once a week thereafter until most of the adults had died. On 15 February 1988, 40 fifth instar nymphs were collected at Millpost and reared in the laboratory at CSIRO; the number that became adult was recorded and observations were continued until all adults had died. A piece of branch with 21 egg slits was also collected from *E. viminalis* at Millpost in August 1987 and eggs were hatched in the laboratory (temp. range 19-21°C). The resulting nymphs were reared to adults.

3.2.3 Fecundity of *E. punctata*

Data collected from 9 February to 1 June 1987 from six trees (data presented in Appendix A, Ant- access Tree Nos. 1E, 1G, 2G, 3H, 5G and 6H) were used to determine the number of eggs laid per female per week. This number was estimated by first dividing the number of egg slits made during the week by the number of females on the tree during that week. The number of females was determined by dividing the number of adults present on a tree by two, assuming a sex ratio of 1:1. The average number of adults present on a tree during a week was calculated as the number of adults present at the start of the week plus the number at the end of the

week, divided by two. Second, the number of egg slits per female per week was multiplied by the mean number of eggs per slit in order to determine the number of eggs laid by a female per week. If less than 1.5 females were present on a tree during any week, these observations were excluded from the calculations.

Pieces of branch containing egg slits were cut from *E. viminalis* at Millpost and at the CSIRO site on Black Mountain, to estimate the number of eggs per slit. Strips with egg slits were collected on 4 February 1987 (from 5 trees) and 11 March 1987 (from 3 trees) and preserved in 70% ethanol. Egg slits were also collected from *E. viminalis* on 21 December 1987 (from 2 trees), 4 January 1988 (from 6 trees) and 4 February 1988 (from 6 trees) and maintained in the laboratory in petri dishes in order to rear egg parasitoids (see section 3.2.4). A piece of wet tissue was placed in each petri dish in order to keep the environment humid. The number of eggs per slit was counted in the preserved and freshly collected egg slits.

3.2.4 Observations on ants

Detailed methods for ant exclusion experiments are described in Chapter 4. However general observations on the interactions between ants, eurymelids and scale insects were made throughout both field seasons.

3.2.5 Parasitism and Predation of *E. punctata* and *E. distincta*

Egg parasitism was estimated from the egg slits maintained in petri dishes in the laboratory (previous section). In the field, nymphs showing parasitoid attacks (presence of external sac-like structure on the lateral sides of the thorax or on the abdomen) were collected and parasitoids were reared in the laboratory. Adults of *E. punctata* and a spider were collected from the study site in December 1988 and kept in a cage in the laboratory to determine whether adults were susceptible to predation by

spiders. The spider was kept for a month, live adults were supplied when needed and observations were made daily.

3.2.6 Estimating the survival rate of individuals in each stage

Data on *E. punctata* collected from December 1986 to July 1987 (second and third generations) from six trees were used for these analyses. The total number of eggs in each generation was obtained by adding the numbers of new eggs recorded on successive sampling days. An attempt was made to separate the cohort of the second generation from that of the third generation.

Three analytical methods were applied to the data in an attempt to estimate the total number of individuals entering each stage. The first was Manly's (1974) method which also had the potential to provide estimates of the survival rate and mean duration of each stage. The required estimates are obtained by fitting a model (Manly's equation (2)) to estimate the number of insects in each stage at various points in time. However, this method was found to be unsatisfactory for analysis of these data due to the occurrence of numerical instability when fitting the model. High variability of the data may have led to incompatibility of the model with the data (Ross Cunningham, pers. comm).

The second was a graphical method (Southwood, 1978) in which the total numbers of individuals entering each stage (N_i) was estimated from a series of estimates on successive sampling days. Successive estimates (i) were plotted against the days, then the area under the curve (A_i) was divided by the mean developmental time (T_i) under field conditions. Mean duration of each stage (nymphs) was assumed to be seven days for the second generation and 12 days for third generation (estimated development time derived from data presented in Appendix A). Survival rate (S_i) in each stage was calculated from the estimations of number of individuals in each stage

using -- $S_i = N_{i+1} / N_i$ where Ni = estimations of the total numbers of individuals entering each stage.

The third method involved the estimation of the total number of individuals in each stage from a series of estimates in successive weeks using a shorter duration for earlier stages than later stages (Farrow 1979 and pers. comm.). This method minimised the problems of overestimation and underestimation of individuals in each stage which probably occurred as a result of the interaction between the duration of an instar and the timing of sampling intervals. Although in the graphical method (Southwood 1978) mean duration of each stage was assumed to be seven days for the second generation and 12 days for the third generation, the actual duration of earlier stages were clearly shorter than later stages as second instars appeared in the same week as hatching started. However, it was not possible to obtain an accurate estimate of the duration of each instar and therefore, assumptions were made based on the range of total developmental time (Appendices. A2 - A7). Three, four, five, seven and 10 days were assumed to be the developmental time for first, second, third, fourth and fifth instars respectively in the second generation (in summer). Seven, eight, 10, 12 and 15 days were assumed to be the duration of first, second, third, fourth and fifth instars respectively in the third generation (in autumn). Steps followed in this method are described below:

(1) A correction factor for each instar was obtained by dividing the count interval (i.e. 7 days) by the duration of that instar.

(2) Total numbers of individuals were taken by adding weekly counts in each instar. On some occasions population counts were made twice a week and an average number was taken from these observation to produce weekly counts.

(3) Total numbers obtained from (2) were multiplied by the factor calculated in (1).

(4) Percentage survival of nymphs in each instar was progessively estimated from the total numbers of eggs laid.

3.3 RESULTS

All data collected at Millpost in the first (Dec. 1986-July 1987) and second (Nov. 1987-June1988) field seasons are presented in Appendices A and B, and only relevant parts of the results are summarized here. General observations made from June 1987 to October 1987 at the study site are presented in Appendix A15.

3.3.1 Life history of *E. punctata*

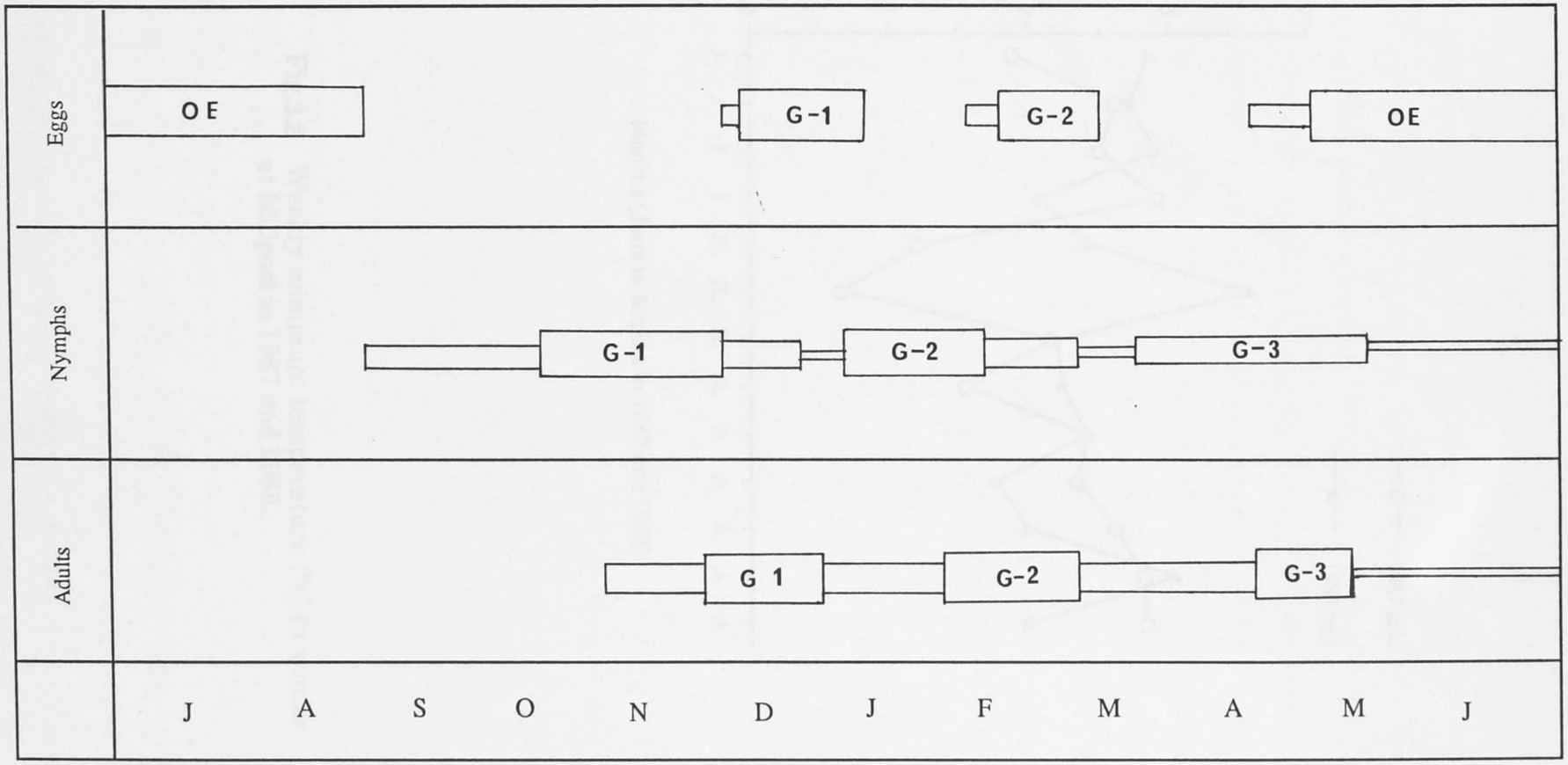
3.3.1.1 Generations

Eurymeloides punctata was found to have three generations per year at Millpost (Fig. 3.1) but the generations were not always entirely distinct. This was especially true for adults, which were quite long lived and hence their generations overlapped. New eggs, nymphs and adults were often present at the same time, and adults were present for most months of the year.

The overwintering eggs laid in late April and May 1987 (autumn), started to hatch in September and October (spring) although some hatching was observed in late August during a spell of warm weather. First generation nymphs and adults were found by November and December1986 and1987; adults started laying eggs in December. These eggs started hatching in January 1987 and 1988. It required four to five weeks for these nymphs to become adults. Adults from this second generation started laying eggs in February 1987 and 1988 and continued until the first week of March. Hatching of these eggs was observed in the middle of March and continued until early April. Nymphs and adults from this third generation appeared in April to June. Egg laying was recorded again in April and May and continued until early June in1987 and July in 1988. Probably the warmer winter temperature in 1988 encouraged the adults to lay eggs for a longer period than in 1987. The weekly minimum winter temperature in 1987 was lower than in 1988 (Fig. 3.2). These eggs overwintered and

Fig. 3.1

Summary of seasonal occurrence of *E. punctata* at Millpost (data collected from Dec.1986 to July 1988). The width of the bars indicates relative abundance. G-1= first generation; G-2= second generation; G-3= third generation and OE= overwintering eggs.


Eggs
OE
G-1
G-2
OE
Nymphs
G-1
G-2
G-3
Adults
G 1
G-2
G-3
J
A
S
O
N
D
J
F
M
A
M
J

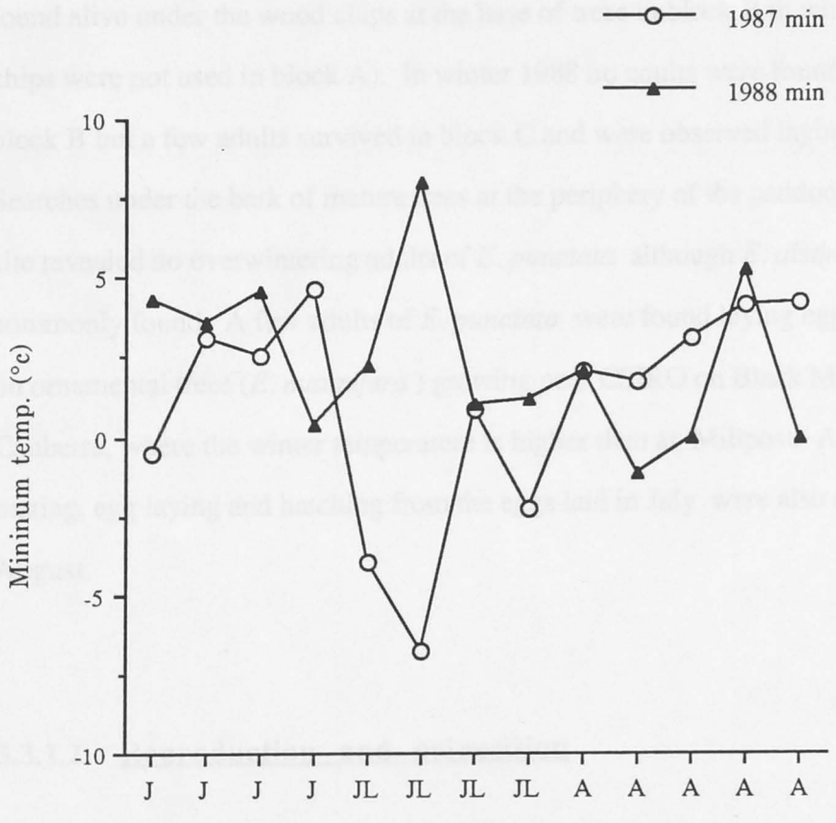


Fig.3.2 Weekly minimum temperature (°c) in winter at Millpost in 1987 and 1988.

hatched in the following spring. Some fourth and fifth instar nymphs which hatched in early April 1987 were found dead in late June probably due to cold weather. However, all adults disappeared by June 1987 from block A, but a few adults were found alive under the wood chips at the base of trees in block B in winter 1987 (wood chips were not used in block A). In winter 1988 no adults were found in block A or block B but a few adults survived in block C and were observed laying eggs until July. Searches under the bark of mature trees at the periphery of the paddock near the study site revealed no overwintering adults of *E. punctata* although *E. distincta* were commonly found. A few adults of *E. punctata* were found laying eggs until July 1988 on ornamental trees (*E. mannifera*) growing near CSIRO on Black Mountain in Canberra, where the winter temperature is higher than at Millpost. A few adults, mating, egg laying and hatching from the eggs laid in July were also noted in late August.

3.3.1.2 Reproduction and oviposition

Mating was observed throughout the summer season at Millpost. *Eurymeloides punctata* adults had a long oviposition period which continued for up to five or six weeks. It was not clear whether a female laid all her eggs on one tree, or whether she also laid on other trees. Eggs were laid in branches which varied from 4.2 to 10.8 mm in diameter (Table 3.1) although branches 2 to 14 mm in diameter were available. Females cut rings of parallel slits from 1.5 to 2.8 mm in length (Table 3.1) along the axis of the branches, deposited the eggs vertically in the slits and covered each slit with a white frothy secretion (Fig. 3.3 and 3.4). The rings were often incomplete and the number of slits in a ring varied from two to 20. The number of eggs per slit ranged from five to 12 with a mean of 8.7 (Table 3.1). Females did not complete a ring of egg slits at each oviposition and did not stay with the slits all the time but came back and added new slits to the incomplete rings or started a new ring. Three or more females sometimes laid eggs close to each other and made a long band of egg rings

Observations	Mean	Range	±SD
Diameter of branches with eggs (mm) n=36	7	4.2 - 10.8	1.5
Length of slits (mm) n=31	2.2	1.5 - 2.8	0.3
No. of eggs in a slit (mm) n=167	8.7	5 - 12	1.7
No. of eggs laid per female per week n=47	33.3	2 - 159	32.4

Table 3.1 Details of egg laying of E. punctata on E. viminalis at Millpost (from Dec. 1986 to June 1988)

Fig. 3.3

An adult female of *E. punctata* laying eggs on *E. viminalis* at Millpost.

Fig. 3.4

Bark removed to expose egg slits of *E. punctata* collected from *E. viminalis* at Millpost

Fig. 3.5 A number of egg rings of *E. punctata* laid by several females on *E. mannifera* at the CSIRO site on Black Mountain.

(Fig. 3.5). After oviposition, scar tissue developed along the edges of the slits causing them to close together but often the egg slits remained open in winter.

3.3.1.3 Egg development

Eggs took from 14 days to four months to hatch depending on the temperature; incubation time varied from two to three weeks in summer to four months in winter. Eggs laid in the glasshouse in February 1987 took 14 days to hatch when the temperature range was 19 to 32°C. Eggs laid in autumn at Millpost overwintered and took about four months to hatch. Eggs from 21 rings (245 slits) laid at Millpost in autumn were collected on 3 August 1987 and reared in the laboratory at 19-21°C. Hatching commenced four days later and continued for a week suggesting that embryonic development was well advanced by late winter (Table 3.2).

3.3.1.4 Hatching

The hatching process, which is similar to that described for other species by Evans (1931), was observed on several occasions. Prior to hatching, the anterior rounded end of an egg became pointed and contained a hard white waxy plug which protected the delicate pronymph and was used to push through the plant tissue. Hatching started with the emergence of the anterior third of the egg from the bark. The plug then broke up and the head of the pronymph appeared beneath the chorion which then split. When about three-quarters of the pronymph had emerged from the bark, its skin split anteriorly, and the nymphal head appeared followed by the rest of the body in a short period of time. Newly hatched nymphs were cream coloured with red eyes and had transparent legs and antennae. Darkening of cuticle occurred in about twenty minutes.

Date	Hatching (no. of 1st instar)	No. of 1st instar transferred to a potted seedling	Adults	Egg slits
7/8/89	13	13		
8/8/87	29	29		
9/8/87	72	72		
11/8/87	256	186		
12/8/87	230	70		
13/8/87	235	35		
15/8/87	30	-		
7/9/87	-	-	1 *	
28/9/87	-	-	12**	
6/10/87	-	-		5
8/10/87	-	-		1
12/10/87	-	-		10

* First appearance of an adult
** All adults (no nymphs present)

Table 3.2 The developmental time required and oviposition period recorded for E. punctata reared on E. viminalis under laboratory conditions. Nymphs were hatched from a branch of E. viminalis with 245 egg slits (21 rings) collected on 3 August 1987.

3.3.1.5 Nymphal development and behaviour

First instar nymphs that hatched in the laboratory required four to six weeks to become adults. This range was taken from the first day of hatching to the first appearance of adults and until the day when all nymphs became adults (Table 3.2).

In the field the newly hatched nymphs usually formed aggregations on the under-surface of the branches and very close to the egg batches from which they had hatched; after about 15-20 minutes they started to feed. Early instars usually fed on young shoots and tips, about 5-10 cm from the tips. Later instar nymphs, which usually fed on more woody branches, were also found on tips of branches or at the bases of the current season's growth. Nymphs, and to some extent adults, especially newly emerged adults, were always gregarious but a large number of new adults dispersed in the first week after emergence (Appendix A). Nymphs of all instars could be found in the same aggregation, sometimes with adults. Occasionally adults were found apparently protecting the early instar nymphs, since young nymphs only became visible after the adults moved following a disturbance. Nymphs and adults were always attended by ants. If disturbed, nymphs did not jump but moved from the aggregation towards the tips or the bases of the branches. After a while they aggregated again. Adults jumped when disturbed and did not immediately return to the same place on the tree. Some may have moved to other trees. When disturbance was minor their reaction was to move to the side of the branch away from the disturbance.

3.3.1.6 Longevity and fecundity of adults

The results of rearing experiments and marking trials showed that in some cases adults survived for four to six weeks (Tables 3.3, 3.4 and 3.5). A preoviposition period of three to four weeks was recorded for adults in the laboratory (Tables 3.2 and 3.3). This range was taken from the first appearance of adults to the time when the first egg slits were recorded. Although fifth instar nymphs could be readily reared on

Date	Total no. of alive adults	Total no. of new egg slits produced
16/2/88	1	-
18/2/88	4	-
19/2/88	7	-
21/2/88	12	-
22/2/88	15	-
23/2/88	17	-
26/2/88	20	-
28/2/88 *	18	-
2/3/88	6	-
4/3/88	3	-
6/3/88	2	-
7/3/88	2	3
8/3/88	2	-
10/3/88	2	-
13/3/88	1	3 (new)
16/3/88	1	-
28/3/88	1	hatching
1/4/88	1	-
3/4/88	-	-

* no nymphs

Table 3.3 Emergence and survivorship of adults of E. punctata reared in the laboratory from 40 fifth instar nymphs collected at Millpost on 15 February 1988.

Date	Observations	Tree nos.			
		R1E	3G	8C	8C
5/3/87	Total no. of adults estimated	20	20	15	14
9/3/87 *	No. of adults marked	2	18	10	16
11/3/87	No. of marked adults recorded	4	5	7	9
12/3/87	"	1	5	7	8
18/3/87	"	0	1	2	2
23/3/87	"	0	0	3	4
1/4/87	"	0	1	0	4
6/4/87	"	0	0	0	2

* Total number of adults was not counted on this occasion

Table 3.4 Results of marking trial at Millpost (Block B) showing total numbers of adults of E. punctata recorded and marked on four trees of E. viminalis and the numbers of marked adults recorded subsequently on the same trees.

Date	plant no. 1		plant no. 2		plant no. 3	
	V th instar	adults	V th instar	adults	V th instar	adults
14/1/88	15	-	20	-	25	-
15/1/88	12	-	20	-	22	2
17/1/88	1	-	14	5	4	7
18/1/88	29(new)	-	7	8	2	6
20/1/88	9	8	-	14	-	1
21/1/88	1	4	-	11	-	-
22/1/88	-	1	-	6	-	-
27/1/88	-	-	-	5	-	-
30/1/88	-	-	-	5	-	-
15/2/88	-	-	-	3	-	-
23/2/88	-	-	-	2	-	-

Table 3.5 Emergence and survivorship of adults of E. punctata from 60 fifth instar nymphs collected at Millpost and reared in a constant temp. room (day temp. 27°c and night temp. 19°c) on E. viminalis.

potted trees in the glasshouse and laboratory, adults generally died in the laboratory without reproducing. The highest numbers of egg slits produced were: eight in the glasshouse from four field collected adult females; 10 from 12 adults (Table 3.2) and 6 from 2 adults (Table 3.3), which were reared in the laboratory from fifth instars nymphs. Thus the results of the rearing trials were unsatisfactory and it was not possible to determine the fecundity of females under controlled conditions.

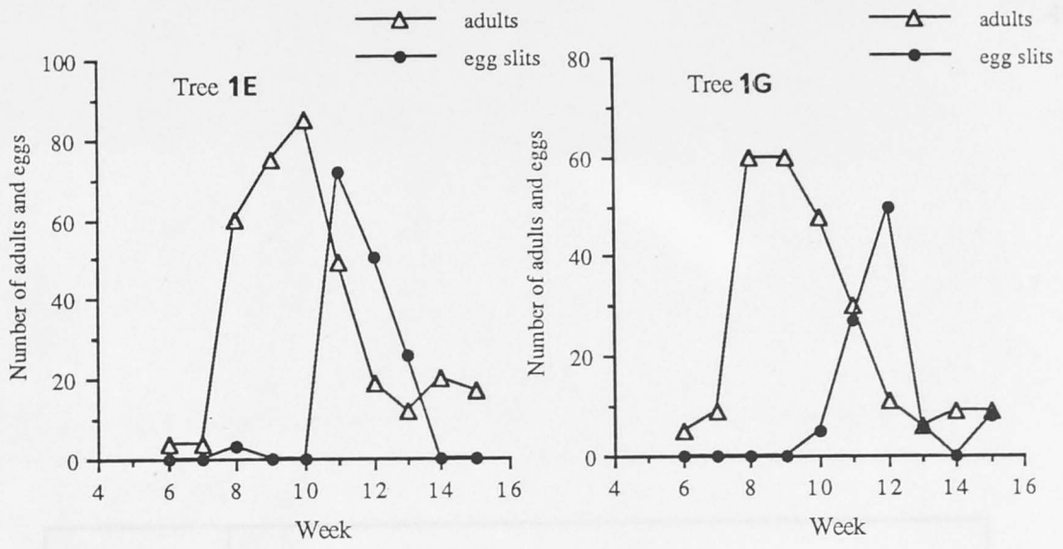
No movement of adults between trees was noted from the marking trial. Despite this, the number of adults fluctuated on the study trees in the field during the egg laying period (Fig. 3.6) indicating that movement between trees probably was occurring. Figure 3.6 shows that the numbers of adults changed from week to week during the egg laying period (from weeks 6 to 15). Therefore it was difficult to directly determine the fecundity of females. The mean number of eggs laid per female per week was estimated as described in section 3.2.3. During the period 9 February 1987 to 1 June 1987, the number of eggs laid per female was 33.3 per week, ranging from 2 to 159 (Table 3.1).

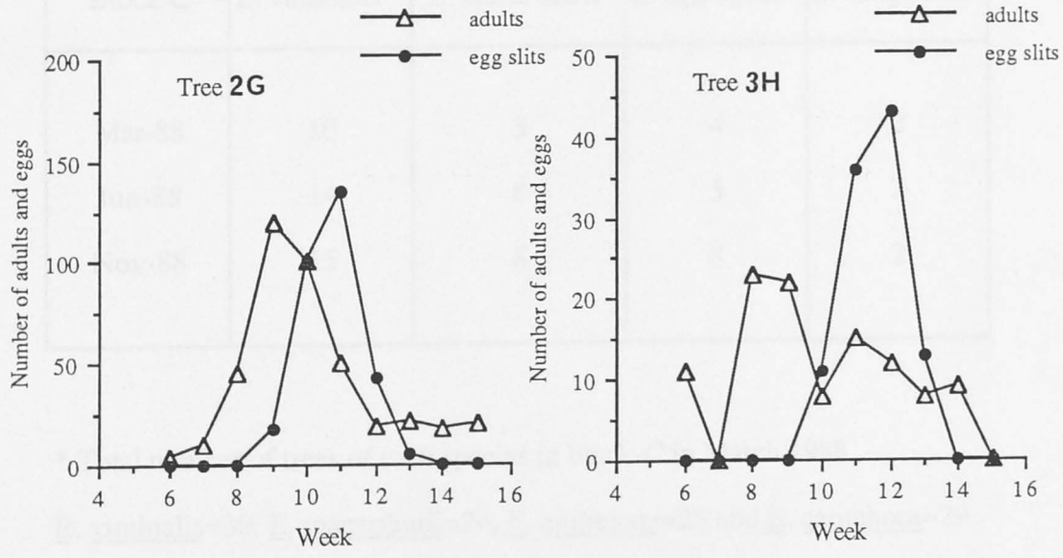
3.3.2 Host -plant associations of *E. punctata*

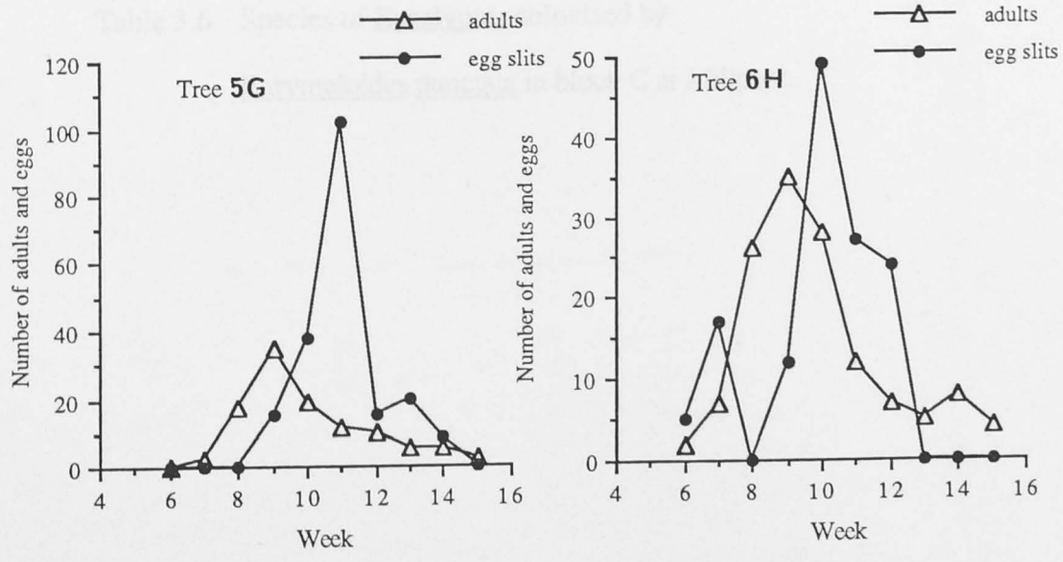
In December 1986 *E. punctata* was only found on *E. viminalis* at Millpost. Over a period of eighteen months to June 1988 a range of eucalypt species was colonised by adults of *E. punctata* at the site. These species were *E. viminalis* , *E. macarthurii* , *E. aggregata* , *E. camphora* , *E. mannifera* , and *E. bridgesiana* . Host plants recorded above are in order of decreasing number of trees colonised by *E. punctata.* From December 1986 until October 1987 most *E. punctata* were found on *E. viminalis* (Block A and B). Observations made in block C from March 1988 to November 1988 are presented in Table 3.6, which shows the host -plant species that were colonised. However, similar numbers of plants of *E. camphora* and *E. aggregata* to *E. viminalis* were colonised by *E. punctata* in another mixed block (block 04) which was planted in 1985 (Fig. 3.7). *E. punctata* was recorded on *E.*

Fig. 3.6

Numbers of eggs of *E. punctata* laid on six trees from weeks 5 to 15 (19 Jan.- 23 March 1987) and numbers of adults present on the trees during that period.


adults
egg slits
Tree 1E
Number of adults and eggs
Week
Tree 1G
Number of adults and eggs
Week


adults
egg slits
Tree 2G
Number of adults and eggs
Week
Tree 3H
Number of adults and eggs
Week


adults
egg slits
Tree 5G
Number of adults and eggs
Week
Tree 6H
Number of adults and eggs
Week

Block C	Number of trees*			
	E. viminalis	*E. macarthurii*	*E. aggregata*	*E. camphora*
Mar-88	10	3	4	2
Jun-88	14	8	5	2
Nov-88	15	8	8	2

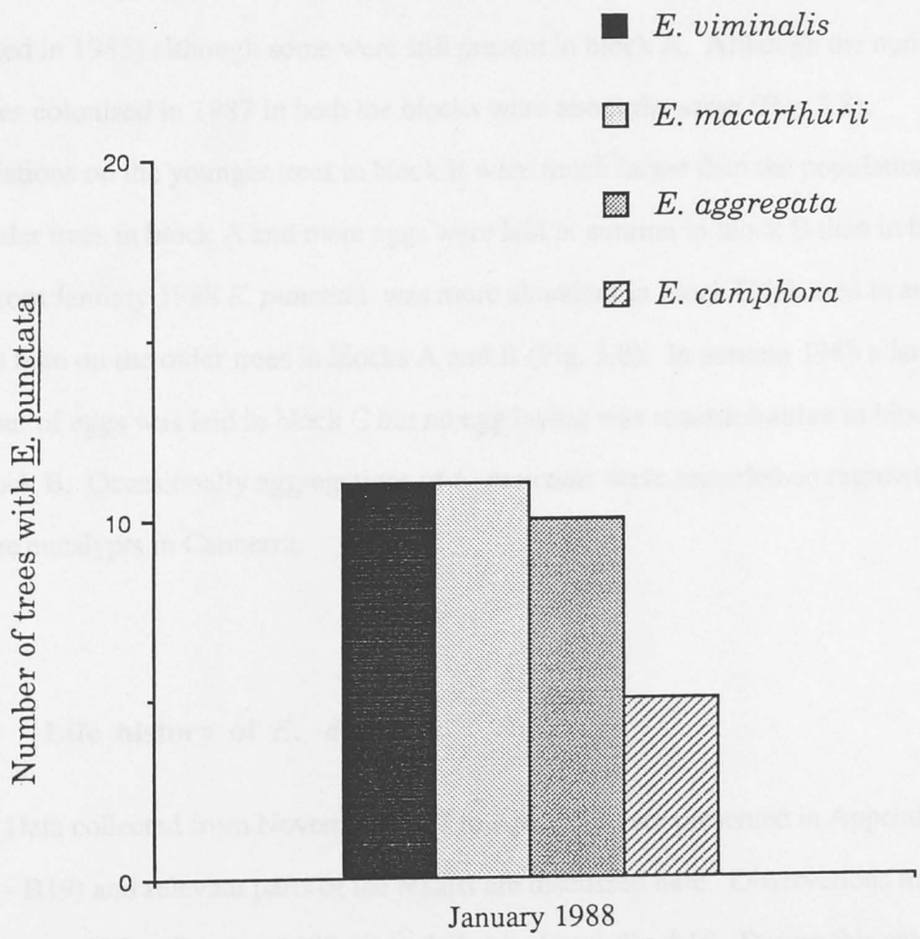
* Total number of trees of each species in block-C in March 1988

E. viminalis=30, E. macarthurii=24, E. aggregata=25 and E. camphora=29

Table 3.6 Species of Eucalyptus colonised by Eurymeloides punctata in block C at Millpost.

Fig. 3.7

Histogram showing numbers of trees of different species of *Eucalyptus* colonised by *E. punctata* in block 04 in January 1988. Total numbers of trees of each species present at that time in the block were *E. viminalis* =24, *E. macarthurii* =22, *E. aggregata* =22 and *E. camphora* =23.


E. viminalis
E. macarthurii
E. aggregata
E. camphora
20
10
0
Number of trees with E. punctata
January 1988

mannifera and *E. bridgesiana* on only a few occasions at Millpost, although *E. punctata* was not uncommon on *E. mannifera* in Canberra.

Eurymeloides punctata tended to be more common on younger than on older trees. In 1986 *E. punctata* was found only on trees planted in 1984 (block A). In 1987, however, it was found in larger numbers on the younger trees in block B (planted in 1985) although some were still present in block A. Although the numbers of trees colonised in 1987 in both the blocks were about the same (Fig. 3.8), populations on the younger trees in block B were much larger than the populations on the older trees in block A and more eggs were laid in autumn in block B than in block A. From January 1988 *E. punctata* was more abundant in block C (planted in autumn 1987) than on the older trees in blocks A and B (Fig. 3.8). In autumn 1988 a large number of eggs was laid in block C but no egg laying was recorded either in block A or block B. Occasionally aggregations of *E. punctata* were recorded on regrowths of mature eucalypts in Canberra.

3.3.3 Life history of *E. distincta*

Data collected from November 1987 to April 1988 are presented in Appendix B (B14 - B19) and relevant parts of the results are discussed here. Observations made from June 1987 to October 1987 are included in Appendix A15. During this study nymphs and adults of *E. distincta* were sometimes found on the same tree, and even in the same aggregation with *E. punctata* . *E. distincta* was univoltine at Millpost. The seasonal occurrence of *E. distincta* is summarized in Figure 3.9. The first appearance of adults of *E. distincta* occurred in late August in block B in 1987 and block C in 1988. *E. distincta* was present from December 1986 to April 1987 in block A but it was not studied in detail. In September and October 1987 mating was observed. Often only one pair of adults were recorded per tree. Egg laying occurred between November and December, although most eggs were laid in November. *E. distincta* also cut slits along the axis of the branches, deposited their eggs and covered them

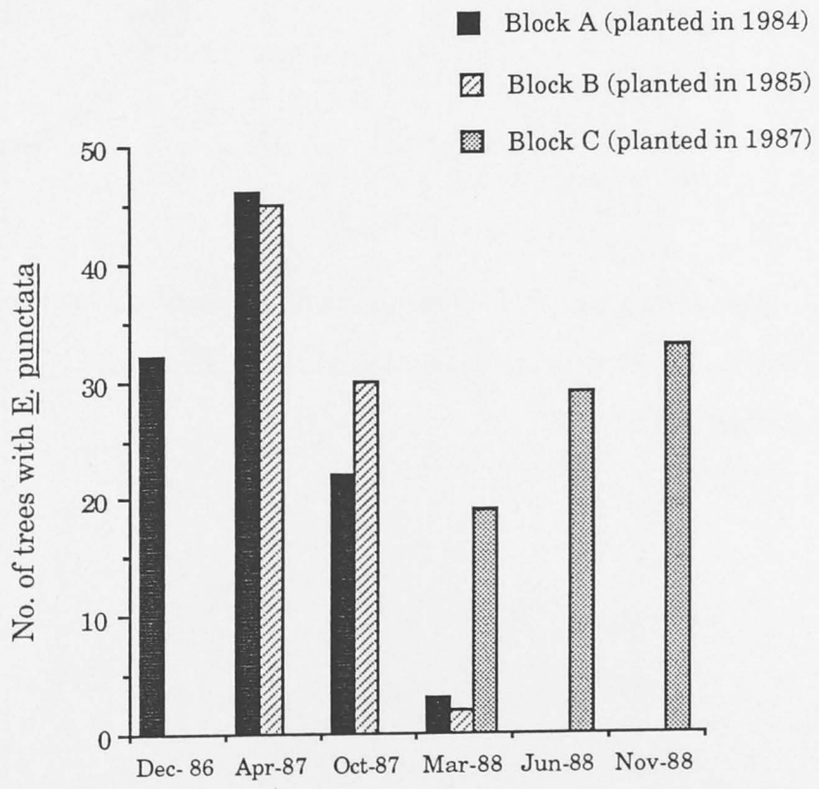


Fig.**3.8** Histogram showing the colonisation pattern of young Eucalypts by E. punctata at Millpost from December 1986 to November 1988.

Fig. 3.9

Summary of seasonal occurrence of *E. distincta* at Millpost (data collected from August 1987 to July 1988). The width of the bars indicates relative abundance.

OA= overwintering adults.

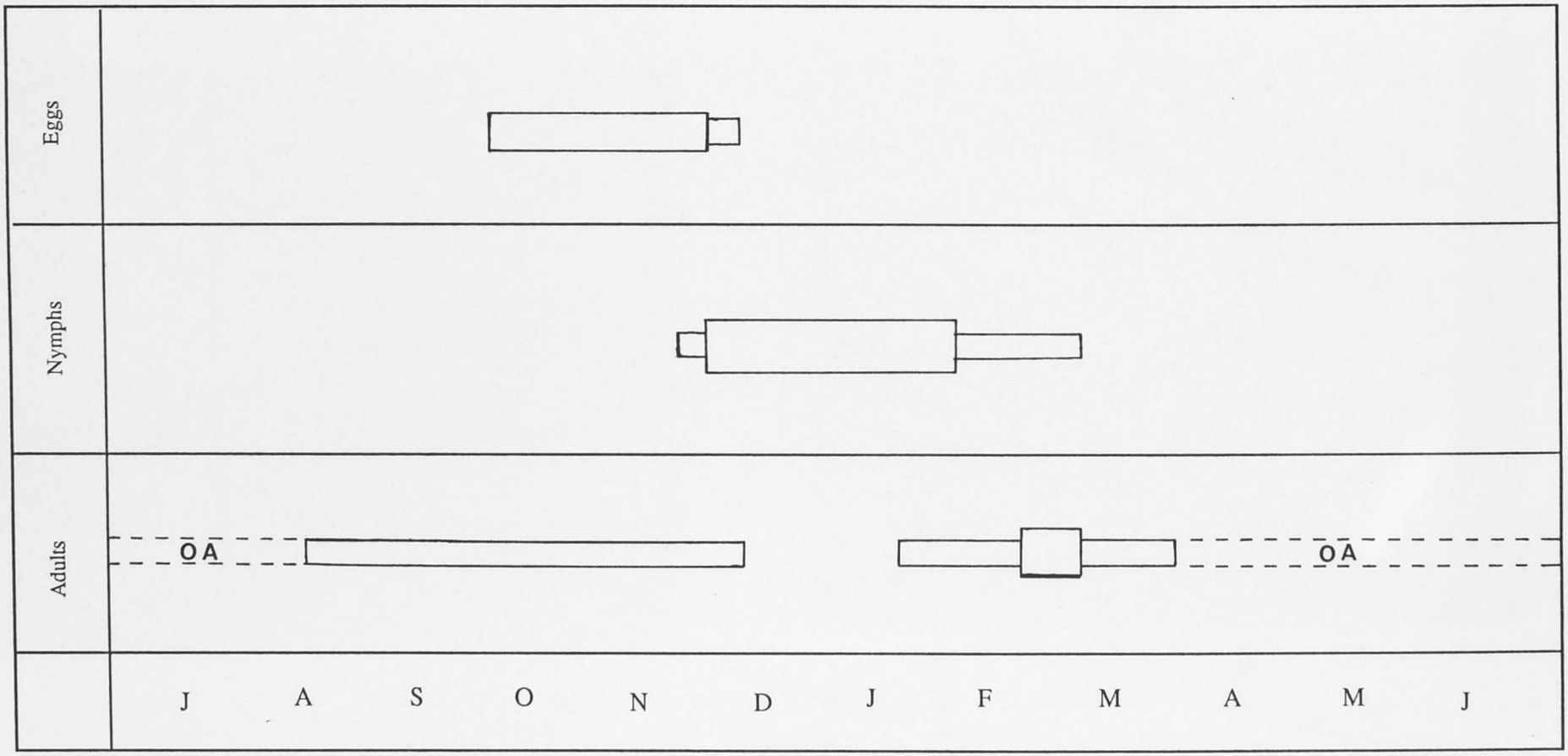

Eggs
Nymphs
Adults
O A
O A
J
A
S
O
N
D
J
F
M
A
M
J

Fig. 3.10

An adult female of *E. distincta* laying eggs on *E. viminalis* at Millpost.

Fig. 3.11

Adult and egg slits of *E. distincta* .

with white secretion (Fig. 3.10). The secretion was distributed more evenly and wider on the slits than it was on the egg slits of *E punctata*. The branches with eggs were wider (15.3-38.3 mm in diameter) and the egg slits were longer (Fig 3.11) than the same of *E. punctata*. Adults were remarkably persistent and some pairs remained at the same site on the same tree throughout the spring and early summer, producing large numbers of egg slits and offspring. Hatching started in late November and new adults appeared in February 1988. All adults disappeared by April. In winter 1988 adults were found under the bark of the nearest mature eucalypts at the study site. At Millpost *E. distincta* was found on *E. viminalis* , *E. aggregata* and *E. macarthurii* and colonised relatively large trees. The trees colonised by *E. distincta* were two metres or more in height and three to five years of age.

3.3.4 Relationship of *E. punctata* and *E. distincta* with ants

The effects of ants on populations of *E. punctata* and *E. distincta* at the study site are described in detail in Chapter 4. Nymphs and adults of both species were always attended by a species of *Iridomyrmex*. No other attending ant species was recorded. On some occasions single adults were attended by up to 20 ants and did not seem disturbed by the presence of the ants. In contrast, adult eurymelids would sometimes leave the tree if lightly touched with a leaf or grass stem held by the observer. Single nymphs also were often found attended by several to many ants. The egg slits of *E. punctata* often were attended by ants even when adults and nymphs were absent. In contrast, the egg slits of *E. distincta* were never attended by ants. On many occasions nymphs and adults of both species were found with female scale insects (Hemiptera : Eriococcidae : *Eriococcus* spp.) especially when the number of eurymelids was low. When ants were excluded from a large population of *E. punctata* and *E. distincta* (see Chapter 4), the eurymelids became contaminated by their own honeydew, especially the highly gregarious nymphs. The branches and leaves on which they aggregated became very sticky and sometimes early instar nymphs got

stuck and died. In some cases adults were noted to have sticky legs and wings which hindered their movement.

3.3.5 Mortality factors

A number of biotic and abiotic factors caused mortality in populations of *E. punctata* and *E. distincta* at Millpost. A range of parasitoids and predators was recorded from eggs, nymphs and adults of both species. Parasitism of eggs and nymphs was observed but adults were never found parasitised. Nymphs and adults were susceptible to predation by other arthropods. Eggs and early instar nymphs were most susceptible to the deleterious effects of weather.

3.3.5.1 Parasitoids

Egg parasitoids: Egg parasitoids of both *E. punctata* and *E. distincta* were reared in the laboratory from eggs collected at Millpost. Two species of unidentified mymarid wasps (Hymenoptera : Mymaridae) were recorded during the study.† The parasitoid species attacking *E. distincta* eggs were larger in size than the species parasitising *E. punctata* eggs. Eggs of *E. punctata* collected from different trees from December 1987 to February 1988 showed 25% - 98% parasitism (Table. 3.7). Hatching of 865 1st instar nymphs (Table 3.2) and emergence of 73 mymarid wasps were recorded from 245 slits (approximately 2132 eggs) in the laboratory in winter which showed that 59% of the eggs failed to hatch and at least 3% of the eggs were parasitised. It is possible that percentage parasitism of eggs of *E. punctata* was higher than 3% since egg slits were not dissected and examined. Percentage parasitism for *E. distincta* eggs was not determined. Parasitised eggs were usually yellowish or brown when collected and became blackened before hatching while unparasitised eggs were white in colour and became a cream colour before hatching.

† Voucher specimens of the mymarid egg parasitoids have been deposited in the Australian National Insect Collection (ANIC), CSIRO, Canberra.

Date of collection	21/12/87		4/1/88						4/2/88				
Tree no.(block)	1E (A)	2G(A)	1A(B)	4 A(B)	R2A(B)	7D(B)	8D(B)	8H(B)	1A(B)	1E(A)	2B(B)	8C+8D(B)	8H(B)
Total no. of eggs	52	75	38	134	91	110	247	408	153	82	33	238	323
% parasitism	69	97	68	25	77	69	68	53	49	98	58	50	38

Table 3.7 Percentage parasitism (by mymarid wasp) of E. punctata eggs collected at Millpost and reared in the laboratory.

Nymphal parasitoid: One species of dryinid wasp (Hymenoptera : Dryinidae : *Anteon* sp.) was reared from nymphs of both *E. punctata* and *E. distincta* . Only one wasp was reared from a single parasitised nymph of *E. punctata.* More than one parasitoid larva was found in most of the nymphs of *E. distincta.* The nymphs of *E. distincta* suffered higher rates of parasitism than those of *E. punctata.* From December 1986 to April 1987 only *E. distincta* nymphs were parasitised (See Appendix A14) but from November 1987 to May 1988 both *E. distincta* and *E. punctata* nymphs were parasitised. Parasitism by this dryinid species was recorded for third, fourth and fifth instar nymphs of *E. distincta* but only for fourth and fifth instar nymphs of *E. punctata.* In the first field season, from 38% to 100% nymphal parasitism was recorded in *E. distincta* (Table 3.8). In the second field season, from 9% to 33% in third, 7% to 75% in fourth and 6 to 83% parasitism in fifth instar nymphs was recorded in *E. distincta* (Tables 3.9 and 3.10). Only a few nymphs of *E. punctata* were found parasitised : one on one tree (1B) in block A (Appendix B2) in 1988 and 22 on two trees in block C in 1988. Thus dryinid wasps did not seem to be a major mortality factor of *E. punctata* .

Wasps reared from field-collected eurymelid nymphs took from two months to one year to emerge after pupation. Three nymphs of *E. distincta* parasitised by *Anteon* sp. were collected in February 1987 (Fig. 3.12). Parasitoid larvae left the hosts and pupated on the day of collection, but the adult wasps did not emerge until late February 1988. Another nymph of *E. punctata* parasitised by *Anteon* sp. was collected on 11 February 1988 , the parasitoid larva left the host and pupated on the day of collection and the adult wasp emerged in mid-late April 1988.

3.3.5.2 Predators

Coccinellid adults and larvae were observed feeding on first and second instar nymphs of *E. punctata* . Three species of Coccinellidae commonly found on the trees were- *Rhizobius ventralis* (Erichson), *Harmonia conformis* (Boisduval), *Coccinella*

Date	Total numbers of nymphs (3rd-5th ins.)	Nos. of parasitisied nymphs	% parasitised
23-Feb-87	40	15	38
27-Feb-87	30	20	67
5-Mar-87	18	18	100
9-Mar-87	12	12	100
11-Mar-87	8	8	100
18-Mar-87	3	3	100

Table 3.8 Percentage parasitism of nymphs of E. distincta on tree 2G

(data collected from 23 Feb to 18 March 1987).

Date	No. of 3rd instars (parasitised)	% parasitised	No. of 4th instars (parasitised)	% parasitised	No. of 5th instars (parasitised)	% parasitised
4-Jan-88	14 (3)	21	10	0	0	0
7-Jan-88	11 (1)	9	7	0	0	0
18-Jan-88	14	0	7 (2)	29	1	0
21-Jan-88	15	0	6 (1)	17	0	0
25-Jan-88	7	0	5	0	2 (1)	50

Table 3.9 Percentage parasitism of nymphs of E. distincta on tree 7A

(data collected from 4 Jan 1988 to 25 Jan 1988).

Date	No. of 3rd instars (parasitised)	% parasitised	No. of 4th instars (parasitised)	% parasitised	No. of 5th instars (parasitised)	% parasitised
25-Jan-88	6 (2)	33	57 (4)	7	0	0
1-Feb-88	0	0	23 (9)	39	16 (1)	6
4-Feb-88	0	0	9 (4)	44	11 (1)	9
8-Feb-88	0	0	4 (3)	75	12 (4)	33
15-Feb-88	0	0	0	0	6 (5)	83

Table 3.10 Percentage parasitism of nymphs of *E. distincta* on tree Tree 1B

(data collected from 25 Jan 1988 to 15 Feb 1988)

Fig. 3.12 A fifth instar nymph of *E. distincta* parasitised by *Anteon* sp.

transversalis (Fabricius). Wings, head capsules and harder body parts of *E. punctata* nymphs and adults were found in spiders nests in the field, and a spider kept in the laboratory ate adults of *E. punctata* , but never during the day. These observations indicate that spiders may be one of the common predators of *E. punctata* at Millpost. Predation by cockroaches (Blattodea), robber flies (Diptera : Asilidae) and shield bugs (Hemiptera : Pentatomidae) was also observed in the field. Other visitors, such as non-predatory flies and wasps, were attracted to the honeydew produced by the eurymelids and scale insects.

3.3.5.3 Weather

Unfavourable weather was an important mortality factor of the eurymelids at Millpost. In July and August 1987 and 1988 many slits were recorded open with dead pronymphs which had failed to hatch due to cold weather; a few hatched successfully but failed to survive. In the second field season heavy rainfall and a hailstorm occurred between weeks 5-8 (Dec 1987), and the number of nymphs, especially early instars, decreased greatly on some trees during that period (Fig. 3.13).

3.3.6 Life-tables of *E. punctata*

Data used for these analyses were extracted from the data presented in Appendix A.

Estimations of the total number of individuals in each stage calculated in the second and the third generations using the graphical method (Southwood 1978) are presented in Table 3.11 and Table 3.12 respectively. The estimates given in Table 3.11 show high variability between trees. The total numbers of individuals entering each stage were inconsistent within a population. For example, in the second generation the total numbers of individuals were higher in the fourth instar than in the third instar on trees 1G, 2G, 3H and 6H. Similarly, the total numbers of individuals

Fig. 3.13

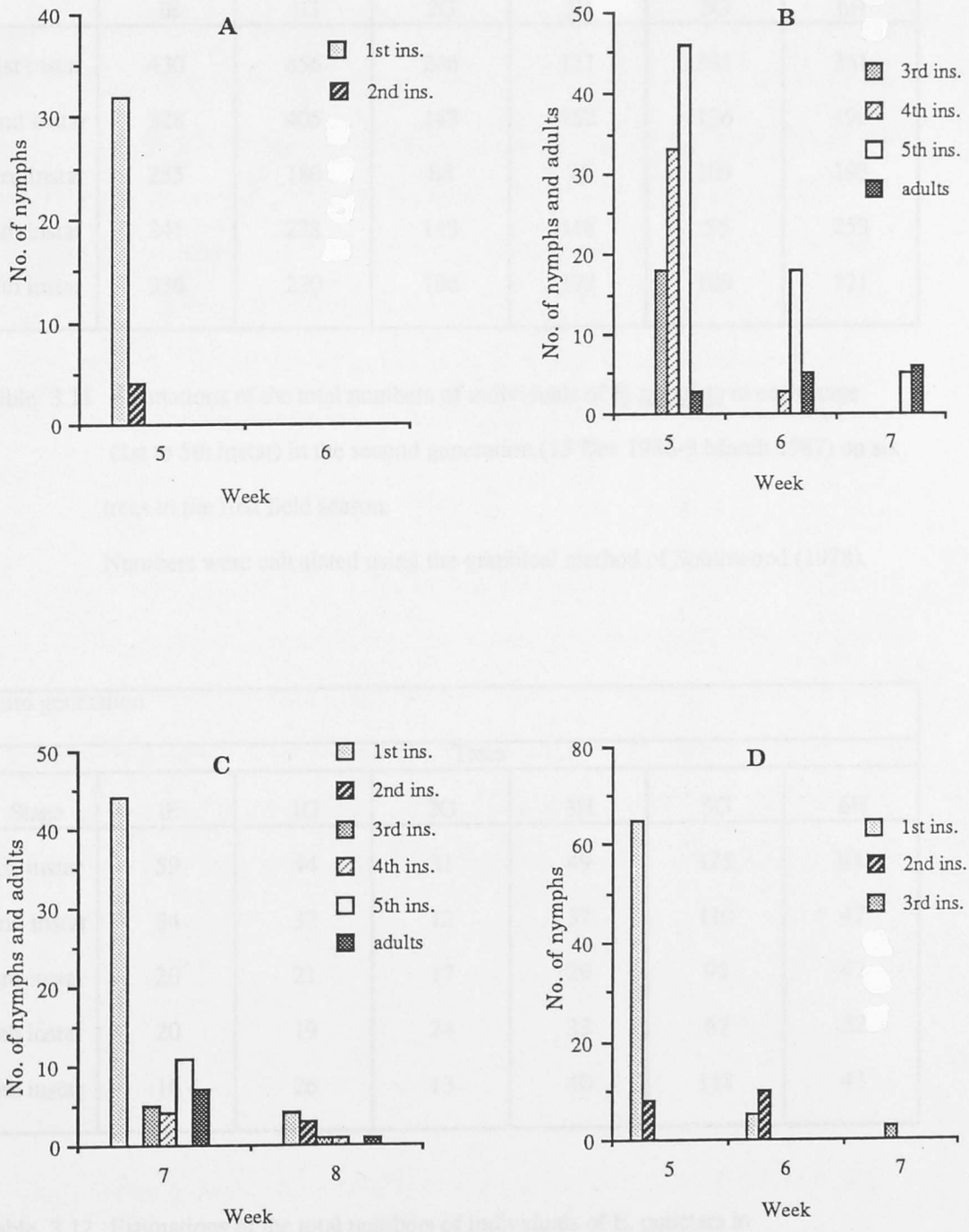
Mortality of eurymelid nymphs between week 5 and 8 due to a hailstorm in week 5 and heavy rainfall in week 7 (data collected from 13 Jan. to 2 Feb. 1987).

A - numbers of nymphs of *E. distincta* on tree 1G (block-A) in weeks 5 and 6.

B - Numbers of nymphs and adults of *E. punctata* on tree 8B (block -A) in weeks 5, 6 and 7.

C - Numbers of nymphs of *E. punctata* on tree 1G (block-B) in weeks 7 and 8.

D - Numbers of nymphs of *E. distincta* on tree 3E (block-A) in weeks 5, 6 and 7.


A
1st ins.
2nd ins.
No. of nymphs
40
30
20
10
0
5
6
Week
B
3rd ins.
4th ins.
5th ins.
adults
No. of nymphs and adults
50
40
30
20
10
0
5
6
7
Week
C
1st ins.
2nd ins.
3rd ins.
4th ins.
5th ins.
adults
No. of nymphs and adults
50
40
30
20
10
0
7
8
Week
D
1st ins.
2nd ins.
3rd ins.
No. of nymphs
80
60
40
20
0
5
6
7
Week

Second generation						
	Trees					
Stage	1E	1G	2G	3H	5G	6H
1st instar	430	856	246	111	381	261
2nd instar	328	405	143	152	136	190
3rd instar	255	180	88	75	109	193
4th instar	241	228	143	118	56	253
5th instar	336	230	106	172	109	121

Table 3.11 Estimations of the total numbers of individuals of E. punctata in each stage (1st to 5th instar) in the second generation (15 Dec 1986-9 March 1987) on six trees in the first field season.

Numbers were calculated using the graphical method of Southwood (1978).

Third generation						
	Trees					
Stage	1E	1G	2G	3H	5G	6H
1st instar	59	44	31	49	125	100
2nd instar	34	37	12	37	110	47
3rd instar	20	21	17	29	92	47
4th instar	20	19	24	33	67	32
5th instar	16	26	13	40	118	43

Table 3.12 Estimations of the total numbers of individuals of E. punctata in each stage (1st to 5th instar) in the third generation (9 Feb. to 29 June 1987) on six trees in the first field season.

Numbers were calculated using the graphical method of Southwood (1978).

were higher in the fifth instar than in fourth on most of the trees in the second and the third generations (Table 3.12).

Total numbers of individuals in each stage on six trees were calculated using Farrow's method (Farrow 1979 and pers. comm.) and the estimates are presented in Table 3.13 (second generation) and Table 3.14 (third generation). Percentage survival of each stage in the second generation is plotted in Fig. 3.14. Highest mortality occurred in the egg stage, and mortality of early instars was higher than that of late instars. Survival from eggs to first instar varied from 23 to 82% and from eggs to fifth instar varied from 3 to 21%. Two inconsistencies resulted from this analysis. On trees 5G and 1E survival was estimated to be higher to the fifth instar than to the fourth instar (Table 3.13).

In the third generation (Fig. 3.15), the highest mortality rate occurred in the egg stage. From 8 to 13% survival was recorded from egg to first instar. From 0.4 to 6% survival was recorded from egg to fifth instar. Survival of eggs was much lower in the third generation than in the second generation. On tree 2G, estimated survival rates were inconsistent during the development period, and on trees 1G and 5G survival from egg to the fifth instar was estimated to be higher than survival to the fourth instar (Table 3.14).

3.4 DISCUSSION

E. punctata is common in NSW especially on young eucalypts. None of the host -plant species recorded at the study site are mentioned in the list presented by Stevens (1985). *E. punctata* was not found on *E. pauciflora* at Millpost although it had been recorded as a host -plant species by Stevens (1985). *E. distincta* has been recorded on *E. bridgesiana* (Evans 1931), but was not found on this species at

Table 3.13

Total numbers of individuals of *E. punctata* surviving in each stage in the second generation (from 15 December 1986 to 9 March 1987) on six trees in the first field season. Numbers were calculated using Farrow's method. Total numbers of individuals in each stage taken from summed weekly counts are presented on the left hand side of each column (n_1) and corrected numbers of the same on the right (n2) for each tree.

Table 3.14

Total numbers of individuals of *E. punctata* surviving in each stage in the third generation (from 9 February to 29 June 1987) on six trees in the first field season. Numbers were calculated using Farrow's method. Total numbers of individuals in each stage taken from summed weekly counts are presented on the left hand side of each column (n_1) and corrected numbers of the same on the right (n2) for each tree.

Second generation

Stages	Trees											
	1E		1G		2G		3H		5G		6H	
	n1	n2	n1	n2	n1	n2	n1	n2	n1	n2	n1	n2
Eggs	1475	-	2344	-	2344	-	521	-	2691	-	4427	-
1st ins.	522	1218	499	1164	240	560	98	228	262	611	558	1302
2nd ins.	364	637	424	742	130	228	111	194	150	263	272	476
3rd ins.	278	389	347	486	114	160	104	146	130	182	183	256
4th ins.	231	231	287	287	156	156	109	109	107	107	203	203
5th ins.	384	269	223	156	112	78	160	112	190	133	160	112

Table 3.13

Third generation

Stages	Trees											
	1E		1G		2G		3H		5G		6H	
	n1	n2	n1	n2	n1	n2	n1	n2	n1	n2	n1	n2
Eggs	1311	-	780	-	2603	-	894	-	1719	-	780	-
1st ins.	105	105	84	84	55	55	73	73	212	212	99	99
2nd ins.	57	50	67	59	21	18	66	58	197	172	87	76
3rd ins.	36	25	41	29	31	22	53	37	153	107	93	65
4th ins.	34	20	31	18	43	25	58	34	112	65	73	43
5th ins.	33	15	43	20	24	11	69	32	212	98	82	38

Table 3.14

Fig. 3.14

Percentage survival of *E. punctata* in each stage (eggs to fifth instar) in the second generation (15 December 1986 to 9 March 1987) on six trees (1E, 1G, 2G, 3H, 5G and 6H) in the first field season. Estimates of survival were calculated using Farrow's method.

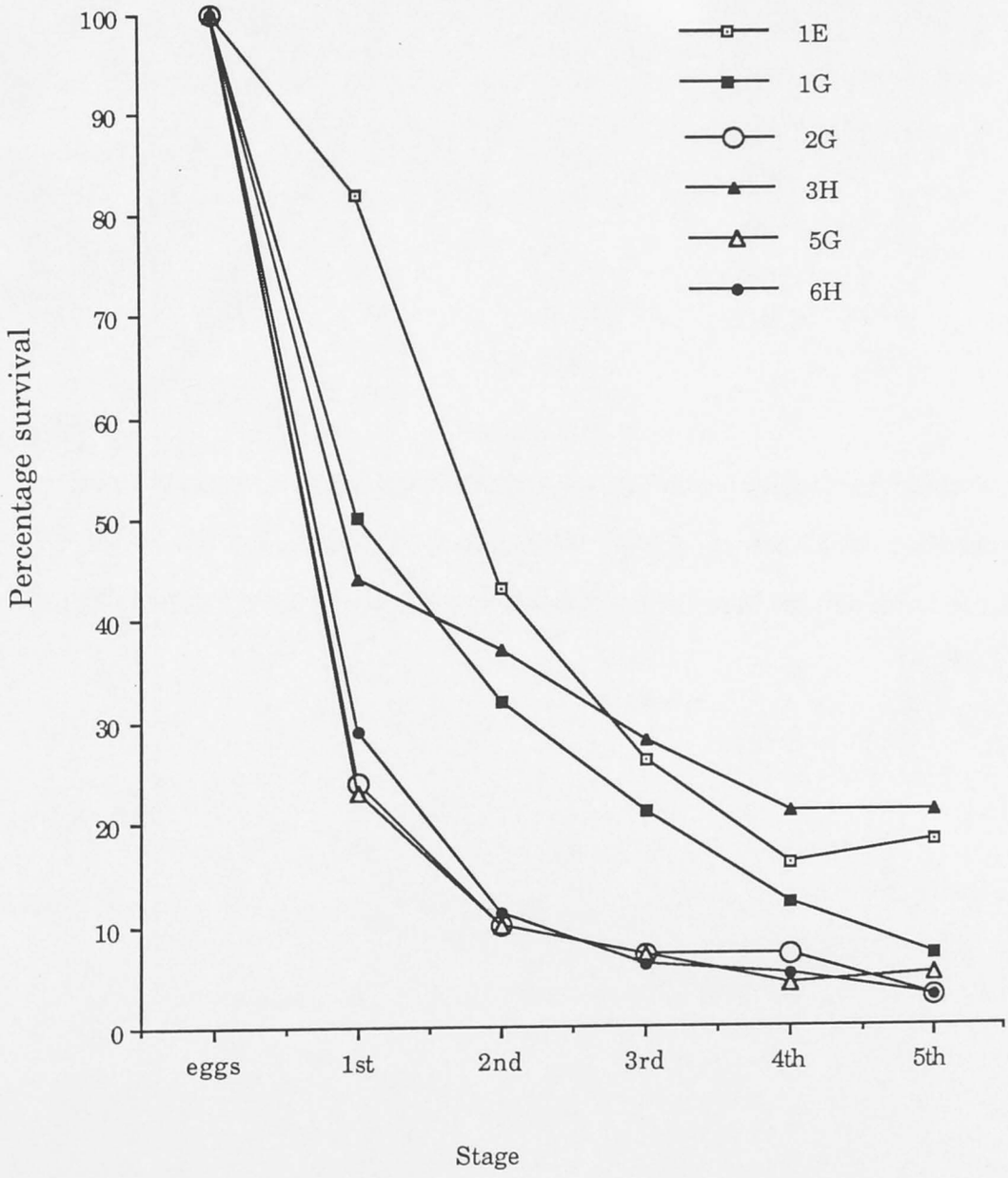
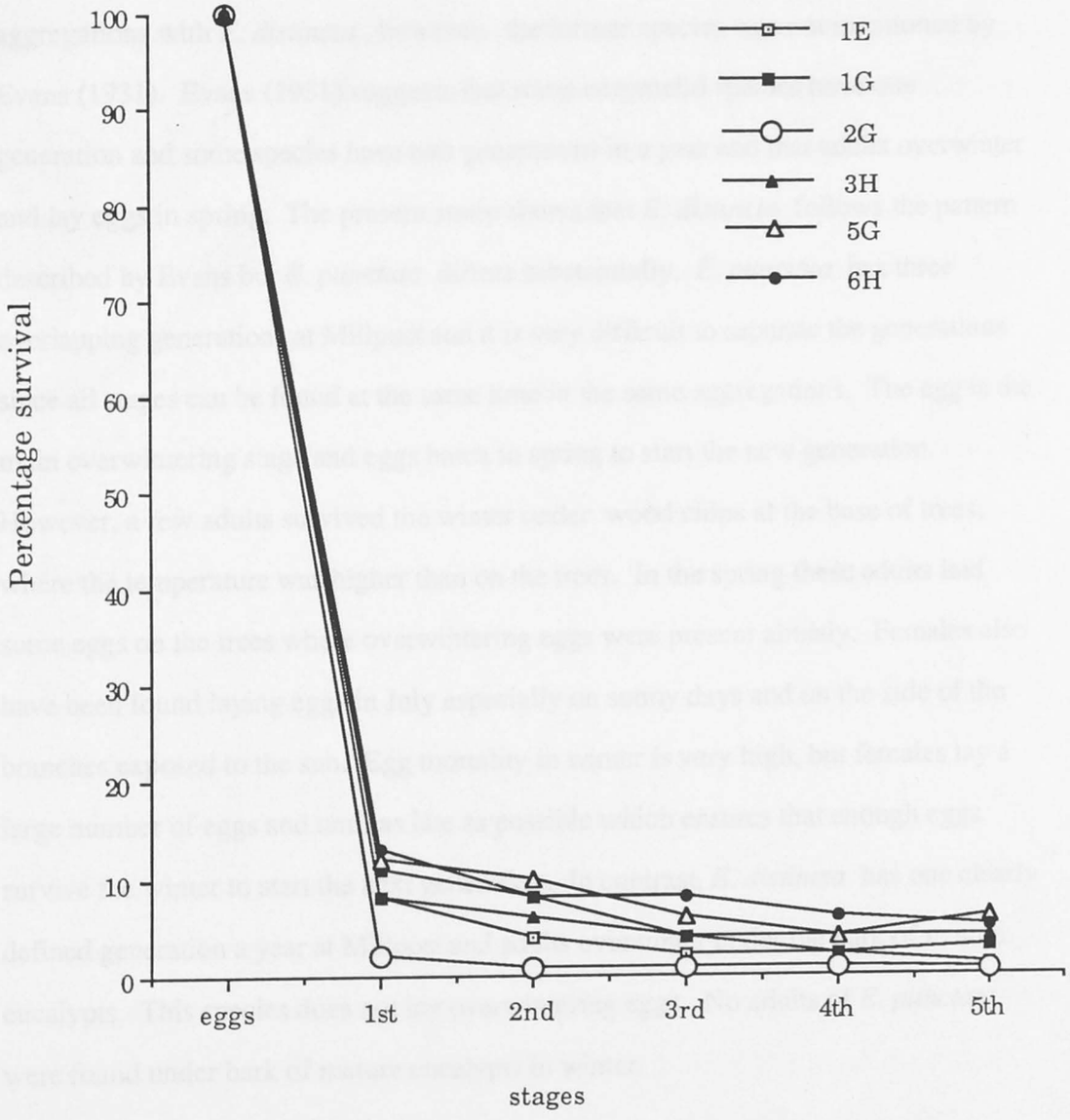

100
90
80
70
60
50
40
30
20
10
0
Percentage survival
1E
1G
2G
3H
5G
6H
eggs
1st
2nd
3rd
4th
5th
Stage

Fig. 3.15

Percentage survival of *E. punctata* in each stage (eggs to fifth instar) in the third generation (9 February to 29 June 1987) on six trees (1E, 1G, 2G, 3H, 5G and 6H) in the first field season. Estimates of survival were calculated using Farrow's method.


Percentage survival
100
90
80
70
60
50
40
30
20
10
0
eggs
1st
2nd
3rd
4th
5th
stages
1E
1G
2G
3H
5G
6H

Millpost. At Millpost both eurymelid species were most common on the same three species of *Eucalyptus* , *E. viminalis* , *E. macarthurii* and *E. aggregata.*

Sometimes *E. punctata* was found at Millpost on the same tree and in the same aggregations with *E. distincta* , however, the former species was not mentioned by Evans (1931). Evans (1931) suggests that some eurymelid species have one generation and some species have two generations in a year and that adults overwinter and lay eggs in spring. The present study shows that *E. distincta* follows the pattern described by Evans but *E. punctata* differs substantially. *E. punctata* has three overlapping generations at Millpost and it is very difficult to separate the generations since all stages can be found at the same time in the same aggregations. The egg is the main overwintering stage and eggs hatch in spring to start the new generation. However, a few adults survived the winter under wood chips at the base of trees, where the temperature was higher than on the trees. In the spring these adults laid some eggs on the trees where overwintering eggs were present already. Females also have been found laying eggs in July especially on sunny days and on the side of the branches exposed to the sun. Egg mortality in winter is very high, but females lay a large number of eggs and until as late as possible which ensures that enough eggs survive the winter to start the next generation. In contrast, *E. distincta* has one clearly defined generation a year at Millpost and adults overwinter under the bark of mature eucalypts. This species does not lay overwintering eggs. No adults of *E. punctata* were found under bark of mature eucalypts in winter.

The eggs of *E. punctata* are attended by ants, whereas those of *E. distincta* are not. The white frothy secretion on the egg slits of *E. punctata* may contain a chemical which attracts ants. *Enchenopa binotata* (Membracidae) also lay their eggs in slits in the branch of a host plant, and cover them with a frothy secretion which protects eggs from desiccation, freezing and parasitism (Wood and Patton, 1971). The study of Wood and Patton (1971) showed that there was a significant difference in survival between covered and uncovered overwintering eggs. The secretion also contains an

ovipositional attractant which leads to the clumping of eggs and thereby to aggregation of nymphs often with adults (Wood and Guttman 1982). Aggregations of nymphs attract ants which ensure protection for eggs and nymphs as well as adults (Buckley 1987b). *E. distincta* eggs are not attended by ants and are probably not directly protected by ants from natural enemies but often adults are found very close to the eggs and they attract ants, which may provide some protection to the eggs. Ants probably also provide some protection from parasitoids to the overwintering eggs of *E. punctata*. Ant attendance is also important for the overwintering stages of other species. Way (1963) suggested that overwintering stages of Homoptera in shelters and in ants' nests are protected from fungi, excessive moisture and very low temperature. Pontin (1960) showed that overwintering eggs of some aphid species are protected by ants.

It is clearly evident from this study that large numbers of eggs are parasitised in the natural state (Tables 3.7, 3.13 and 3.14) and egg parasitism is probably the main mortality factor affecting these populations of eurymelids. Mortality in the egg stage has also been recorded as the main factor regulating the populations of other homopterans (Waloff and Thompson 1980; Cookson and New 1980). Only one parasitoid (Mymaridae, unidentified) has been found in each host egg of *E. punctata* examined. Rothschild (1966b) also found only one larva of the parasitoid wasp *Anagrus* sp. (Mymaridae) in each host egg of *Conomelus* (Delphacidae). However, it is not uncommon to have more than one parasitoid of the same species in one host egg of *Tettigella viridis* (Cicadellidae), although unparasitised eggs are greatly preferred by the parasitoids (Whalley 1969). Vinson (1976) also suggested that unparasitised hosts are preferred by the parasitoids. There are two possible explanations for the occurrence of only one parasitoid per host egg of *E. punctata* . First,*E. punctata* has three overlapping generations and new eggs are available for a long period of time, and therefore, parasitoids may easily avoid host eggs which are already parasitised. Second, the number of parasitoids per host egg may be determined by the relative size of the host and parasitoid. Although the numbers of

parasitoids per host (the third, fourth and fifth instar nymphs of *E. distincta*) were not quantified, the number probably depended on the size of the host. Askew (1971) suggested that the numbers of parasitoids developing on a host depend very much on the size of the host.

Only one parasitoid larva was also found in each host egg of *E. distincta*. *E. distincta* overwinters as an adult and a large number of its eggs are parasitised during spring and summer (Evans 1931; observations made during this study), but it is not known what happens to the parasitoids during winter.

The estimated total numbers of individuals entering each stage using Southwood's (1978) graphical method were highly inconsistent. There may be several causes for these inconsistencies. Instar durations were not equal, and were usually longer in the later instars than in the earlier instars, and the counting intervals were not always regular. Therefore, it is possible that (i) some individuals in the later instars were counted more than once in each instar or (ii) some individuals were not counted in their earlier instars but were counted in their later instars. Although more accurate estimates were obtained by using regular sampling intervals and shorter duration for earlier stages than later stages, inconsistencies occurred on some occasions, for example, on trees 5G and 1E in the second generation and 2G in the third generation. It is also possible that counting errors contributed to the inconsistencies in the estimates. Errors were unavoidable because of the gregarious nature of nymphs and their tendency to move if disturbed which made them very difficult to count.

C HAPTER - FOUR

ASSOCIATION BETWEEN ANTS AND EURYMELIDS

4.1 INTRODUCTION

It is well known that populations of Homoptera appear to increase in numbers when they are attended by ants (Flanders 1951; Nixon 1951). Grant and Moran (1986) studied the effects of foraging ants on arboreal insect herbivores in an undisturbed woodland savanna and showed that trees from which ants have been excluded have significantly less homopterous individuals and species than the control trees. Many studies have shown the intimate positive association between ants and honeydew producing insects (Way 1963). The ant attendance mainly protects the homopterans from their natural enemies and improves hygiene by removing the honeydew produced by the homopterans (Wood 1974; 1977; Gough 1975; Collins and Scott 1982; Fritz 1982; Bristow 1983; Buckley 1983; 1987a; 1987b; Beattie 1985; Maschwitz, Fiala and Dolling 1987).

The effects of ants on eurymelid populations have not yet been documented. This study investigates the effects of ant attendance on eurymelid populations by setting up an ant-exclusion experiment. For this experiment the eurymelid leafhoppers of each tree are regarded as constituting a population although the ability of adults to move between trees means that the populations are not discrete. The main aims of the ant-exclusion experiment were to

determine whether:

i. presence of ants increases the survival rate of individuals in all or a particular stage of development.

iii. presence of ants increases or decreases developmental rate of individuals.

ii. presence of ants encourages adults to stay on the tree and to oviposit.

4.2 METHODS

All observations for the ant-exclusion experiment were made at Millpost over two field seasons from December 1986 to June 1988. The study site and tree block designs are described in Chapter 1. Both *Eurymeloides punctata* and *Eurymela distincta* were found on other species of *Eucalyptus* during the second field season but not in sufficient numbers for experimentation. Therefore, monospecific blocks of *E. viminalis* were used for all observations for these experiments. During the first field season block A was used for the ant-exclusion experiment and during the second field season block B was used in conjunction with block A because block A had insufficient trees suitable for experimental manipulations.

4.2.1 Design of the ant-exclusion experiment

This experiment was designed to compare the populations of *E. punctata* and *E. distincta* on trees with and without ants. In the natural state all populations of *E. punctata* and *E. distincta* were attended by ants of an *Iridomyrmex* sp. Therefore to create ant-free populations the ants were deliberately excluded from one member of each of six pairs of experimental trees by the presence of sticky barriers. These barriers consisted of a band of Tangletrap® about 8 cm wide, attached to the tree trunk approximately 10 cm from the ground. During the second field season insulating tape was used on the tree trunks and a band of Tangletrap about 3 cm wide was put on the tape. Fresh Tangletrap was reapplied, as required, throughout the experiments. Ants had free access to the control trees. Pairs of trees were selected, based on similarities in tree age, architecture, position in the plot, and initial size of the population of eurymelids on the trees.

During the first field season six pairs of trees in block A with *E. punctata* were chosen and on 11 December 1986 ants were excluded from one tree of each pair. Observations were started on 15 December 1986 and continued until July 1987. At the beginning of this experiment nymphs from the second generation and some later instar nymphs from the first generation were present on the trees. During the second field season five pairs of trees from block A and one pair from block B were chosen. Ants were excluded from one of each of these six pairs on 9 November 1987 and observations were started on the same day and continued until June 1988. Nymphs from the first generation were present at the beginning of this study. The experimental design was complicated during the second field season because of the presence of increased numbers of *E. distincta* . Of the six pairs of trees, three pairs contained both *E. punctata* and *E. distincta* , and three pairs contained only *E. punctata.*

4.2.2 Data collection

Population counts were made on the ant-excluded and control (ant-access) trees at about weekly intervals. On some occasions population counts were made twice a week and an average number was taken from those two observations to estimate weekly counts. Population counts were made as described in the methods in Chapter 3. On different days counting of individuals on the trees was started from different trees and from lower branches to the upper branches or vice versa. Observations were made until no individuals were left at the end of the season. Individuals caught on the Tangletrap bands were collected at intervals and counted. Adults from the bands were sexed by differences in the external genitalia and the colour of the ventral sides of the abdomen (see section 2.5 in Chapter 2).

4.2.3 Comparing different stages between ant-access and ant-excluded trees

This section has two basic approaches: (1) graphical presentation of the data and (2) estimation of the total numbers of individuals entering each stage on the ant-access and the ant-excluded trees.

4.2.3.1 Graphical presentation of the data

The effects of the presence of ants on different developmental stages of *E. punctata* and *E. distincta* are highlighted by graphical presentation of population numbers on ant-access and ant-excluded trees. Logarithms of the total number of individuals plus one [log(x+1)] in each stage were summed for all ant-access and all ant-excluded trees for each week and plotted. Total numbers of individuals [log(x+1)] in each stage in successive weeks was also plotted for both members of each pair of

trees. Numbers of new egg slits of *E. punctata* in each week were multiplied by the average number of eggs per slit (8.7) to calculate the total number of eggs. The same method was applied for data collected for *E. distincta,* except that numbers of egg slits were plotted instead of numbers of eggs.

4.2.3.2 Comparing the survival rate of individuals in each stage on the ant-access and ant-excluded trees

Data on *E. punctata* collected from January 1987 to July 1987 (second and third generations) for six pairs of trees were used for these analyses. The method of Southwood (1978) as described in section 3.2.6 in Chapter 3 for the ant-access trees was used to estimate the total number of individuals entering each stage in each generation on the ant-excluded trees. Total numbers of individuals and percentage survival in each stage in the second and third generations on the ant-excluded trees were also calculated using Farrow's method (Farrow 1979, pers.comm.) as described in section 3.2.6 in Chapter 3 in order to compare them with the same on the control (ant-access) trees.

4.2.4 Average population age

A measure of average population age was used to determine if there was any difference between the developmental rate of nymphal individuals of *E. punctata* on ant-access and ant-excluded trees. Data collected from 5 January 1987 to 11 March 1987 were used for this analysis. For each sampling date, average population age was calculated as $\sum n_i I_i / \sum n_i$, where, I_i= instar number and n_i= number of individuals in that instar.

The average population age of the individuals on successive days on ant-access and ant-excluded trees was plotted against time for each tree pair and plotted lines were described by quadratic equations. Then the slope, b_1, and curvature, b_2, parameters

of these curves were compared between ant-access and ant-excluded trees of each pair using a paired t-test.

4.3 RESULTS

All data collected during the first (December 1986 to June 1987) and second (November 1987 to June 1988) field seasons are presented in Appendix A and B respectively.

4.3.1 Graphical presentation of the data

4.3.1.1 First field season

The overall differences between the populations of *E. punctata* on ant-access and ant-excluded trees in the first field season are summarised in Fig. 4.1. In general, it was clear from the results that ants did not have any direct effect on the second generation of *E. punctata* but the removal of ants had negative effects on the third generation, for example, failure to hatch and reduction in number of individuals of nymphal and adult stages (Fig. 4.1). These effects were not pronounced until week 10-15 except for pair 3H-1F (Fig. 4.2).

The numbers of adults recorded on both ant-access and ant-excluded trees fluctuated throughout the season in a similar manner from tree to tree (Figs 4.2 - 4.7). In pairs 3H-1F (Fig. 4.2), 1C-1G (Fig. 4.3) and 1E-1B (Fig. 4.4), fewer adults were present on ant-excluded trees than on ant-access trees and these adults laid very few or no eggs after week 5 on ant-excluded trees. In pair 2G-2F (Fig. 4.5) about the same number of adults were present on both trees until week 18 but many fewer eggs were laid on the ant-excluded tree than on the ant-access tree. Although some hatching was

Fig. 4.1

Total numbers of individuals of *E. punctata* in each stage on six pairs of trees in the first field season (Dec. 1986-July 1987)

■ = ant-access

◇ = ant-excluded

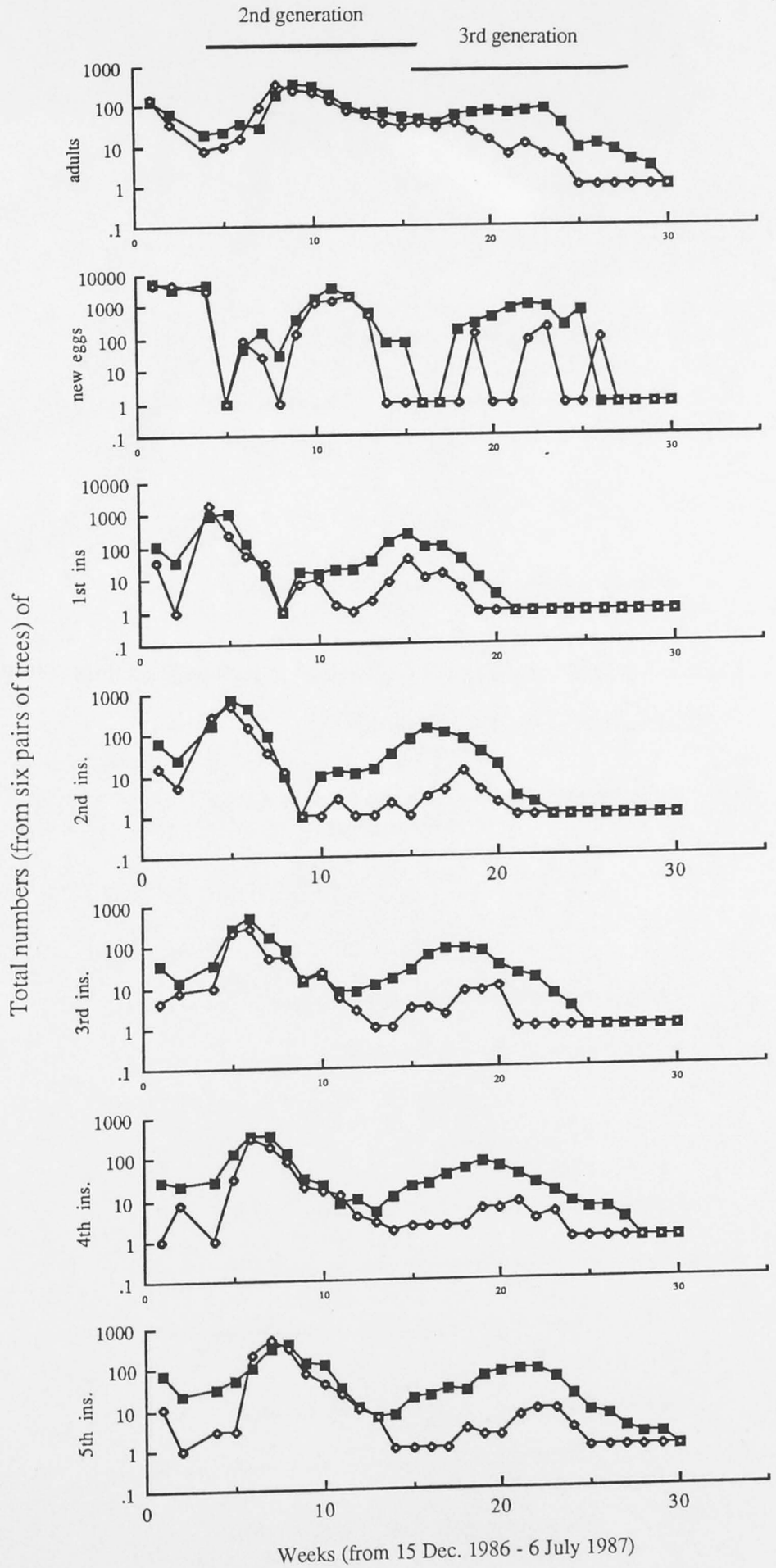

2nd generation
3rd generation
adults
new eggs
1st ins
2nd ins.
3rd ins.
4th ins.
5th ins.
1000
100
10
1
.1
10000
0
10
20
30
Total numbers (from six pairs of trees) of
Weeks (from 15 Dec. 1986 - 6 July 1987)

Fig. 4.2

Total numbers of individuals of *E. punctata* in each stage on trees 3H-1F in the first field season (Dec. 1986 - July 1987).

■ = ant-access

◆ = ant-excluded

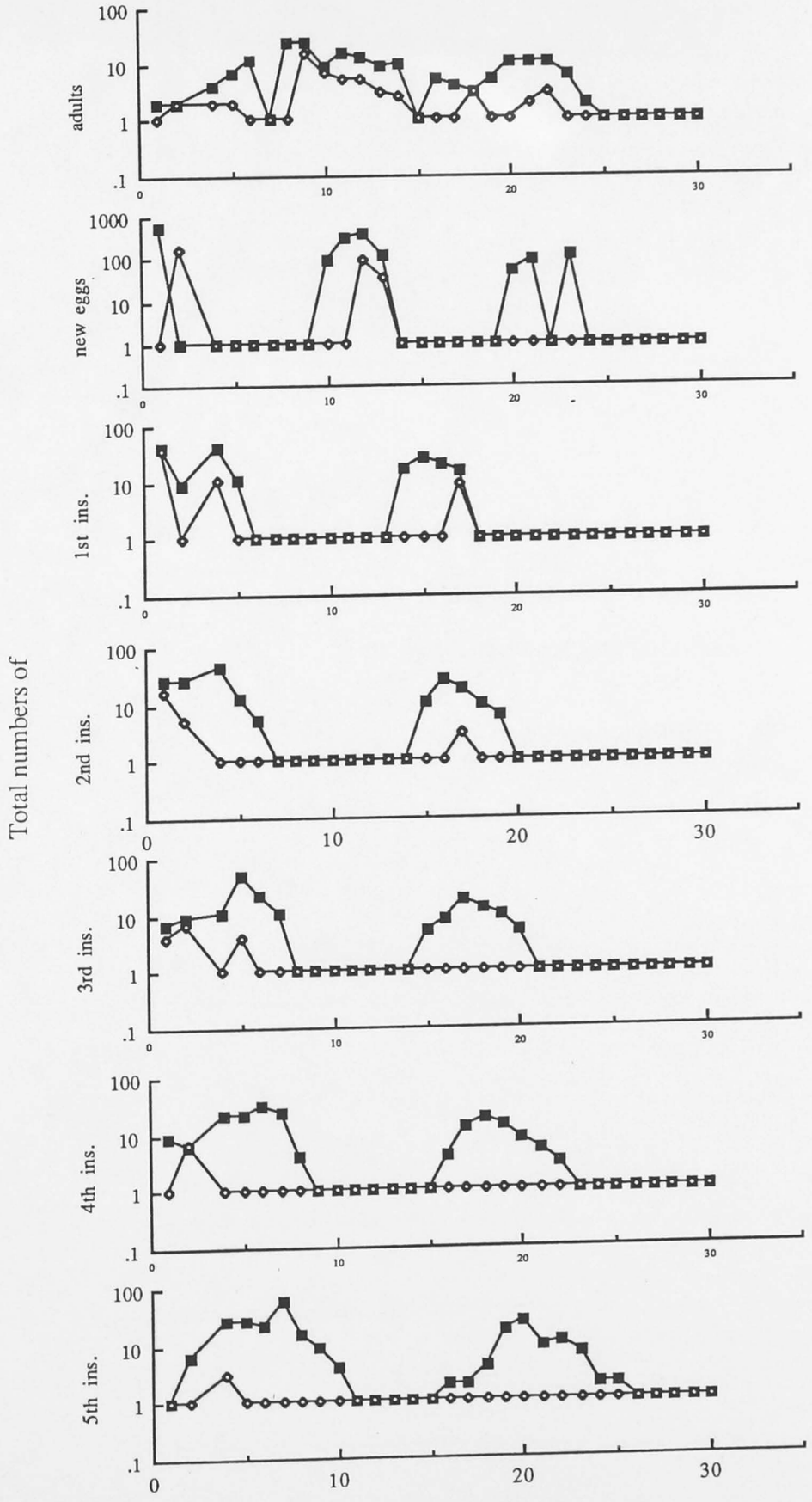

Total numbers of
adults
new eggs
1st ins.
2nd ins.
3rd ins.
4th ins.
5th ins.
100
10
1
.1
1000
0
10
20
30
Weeks (from 15 Dec. 1986 - 6 July 1987)

Fig.4.3

Total numbers of individuals of *E. punctata* in each stage on trees 1G-1C in the first field season (Dec. 1986 - July 1987).

■ = ant-access

◇ = ant-excluded

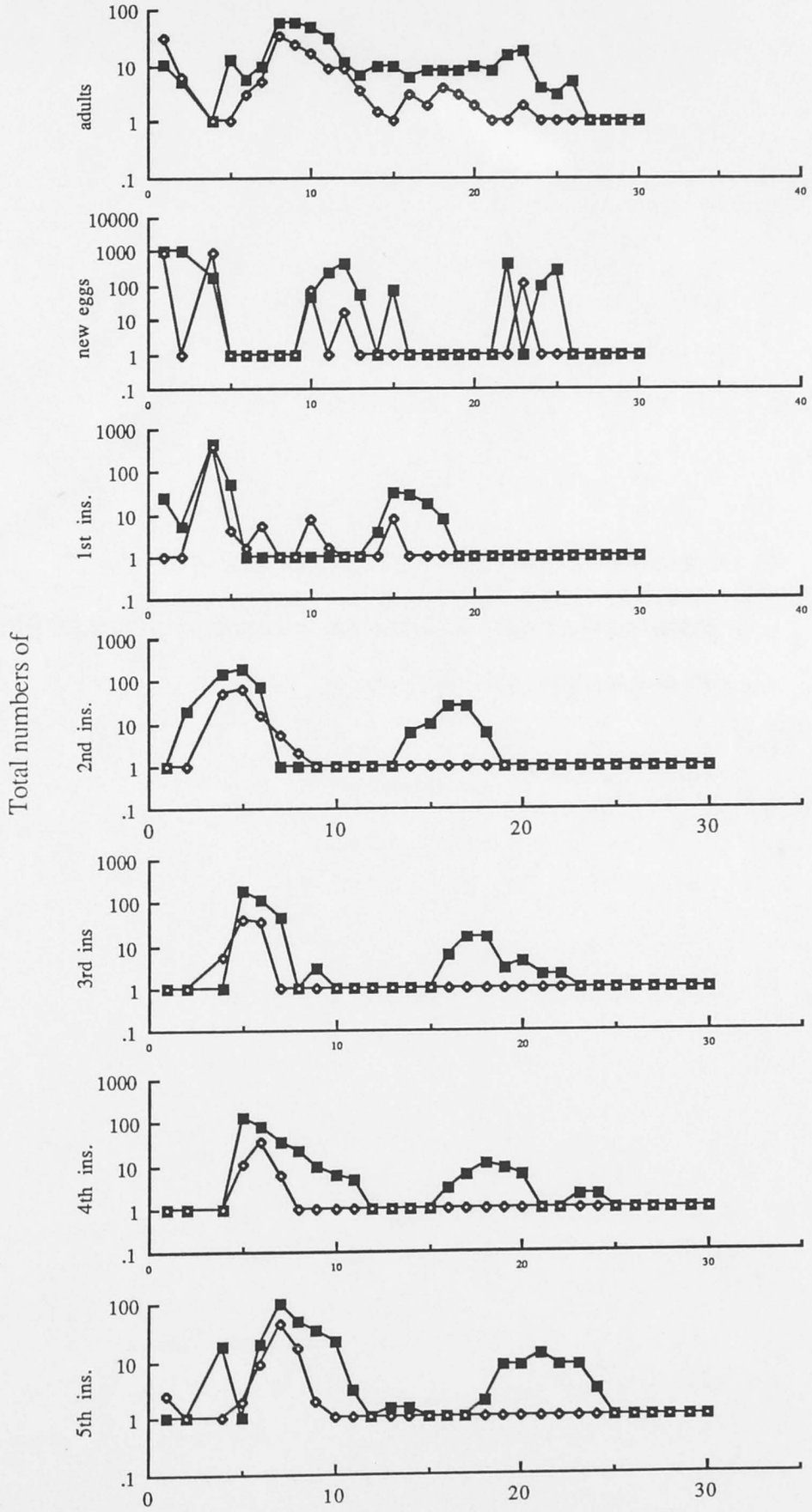

Total numbers of
adults
new eggs
1st ins.
2nd ins.
3rd ins
4th ins.
5th ins.
100
10
1
.1
10000
1000
0
10
20
30
40
Weeks (from 15 Dec. 1986 - 6 July 1987)

Fig. 4.4

Total numbers of individuals of *E. punctata* in each stage on trees 1E-1B in the first field season (Dec. 1986 - July 1987).

■ = ant-access

◇ = ant-excluded

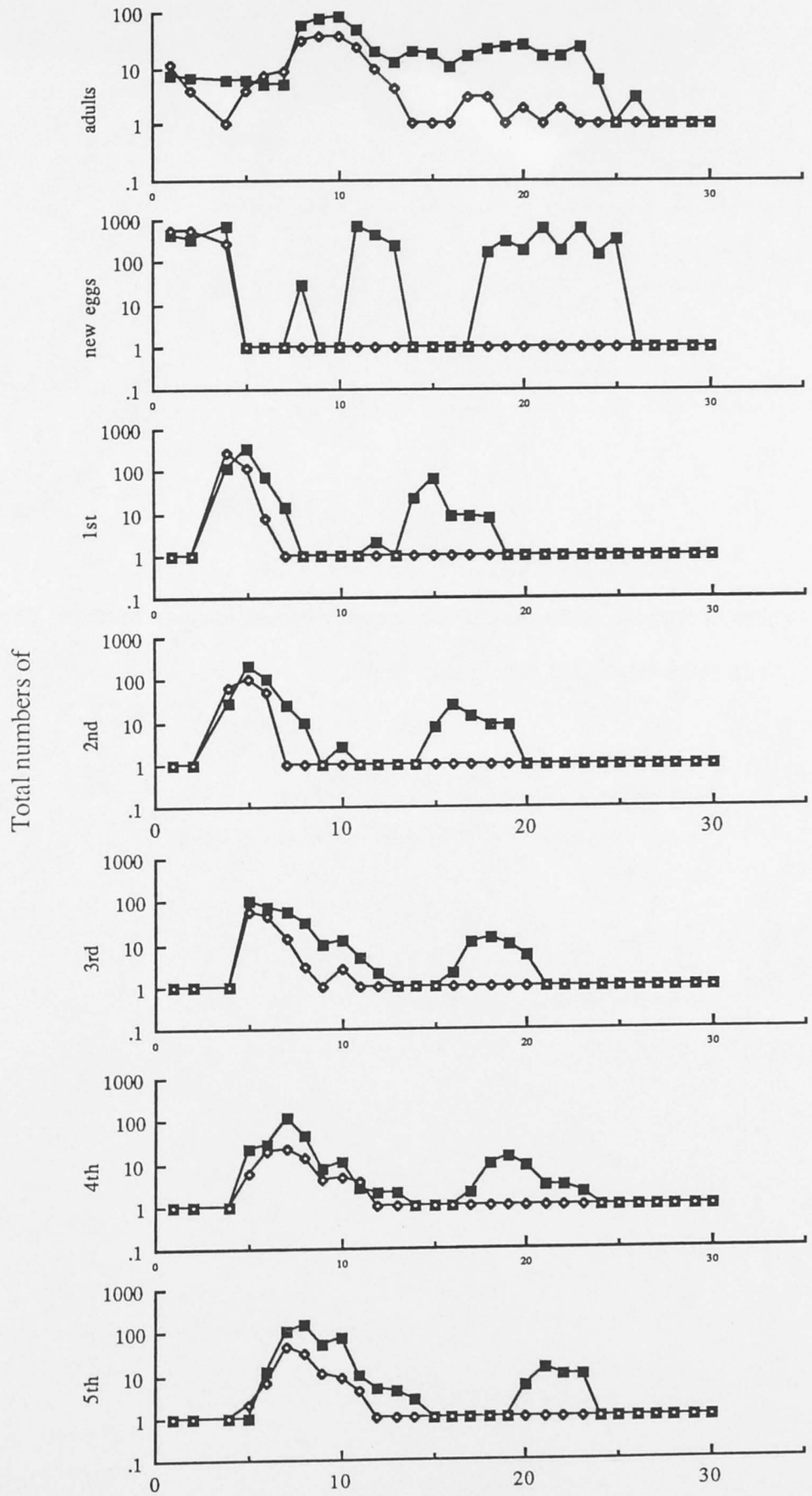

Total numbers of
adults
new eggs
1st
2nd
3rd
4th
5th
100
10
1
.1
1000
0
10
20
30
Weeks (from 15 Dec. 1986 - 6 July 1987)

Fig. 4.5

Total numbers of individuals of *E. punctata* in each stage on trees 2G- 2F in the first field season (Dec. 1986 - July 1987).

■ = ant-access

◆ = ant-excluded

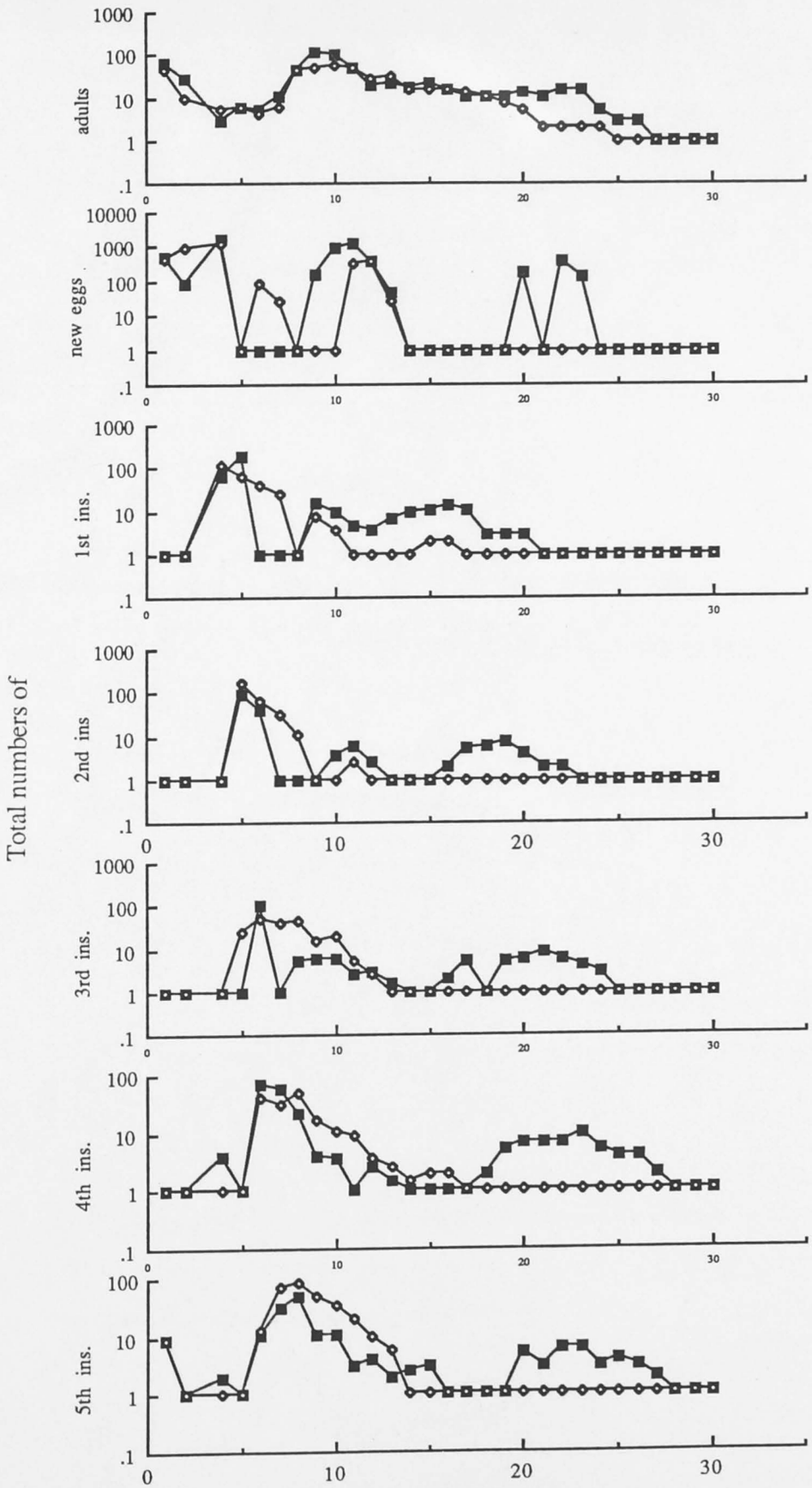

Total numbers of
adults
new eggs
1st ins.
2nd ins
3rd ins.
4th ins.
5th ins.
1000
100
10
1
.1
10000
0
10
20
30
Weeks (from 15 Dec. 1986 - 6 July 1987)

Fig. 4.6

Total numbers of individuals of *E. punctata* in each stage on trees 6H-8H in the first field season (Dec. 1986 - July 1987).

■ = ant-access

◆ = ant-excluded

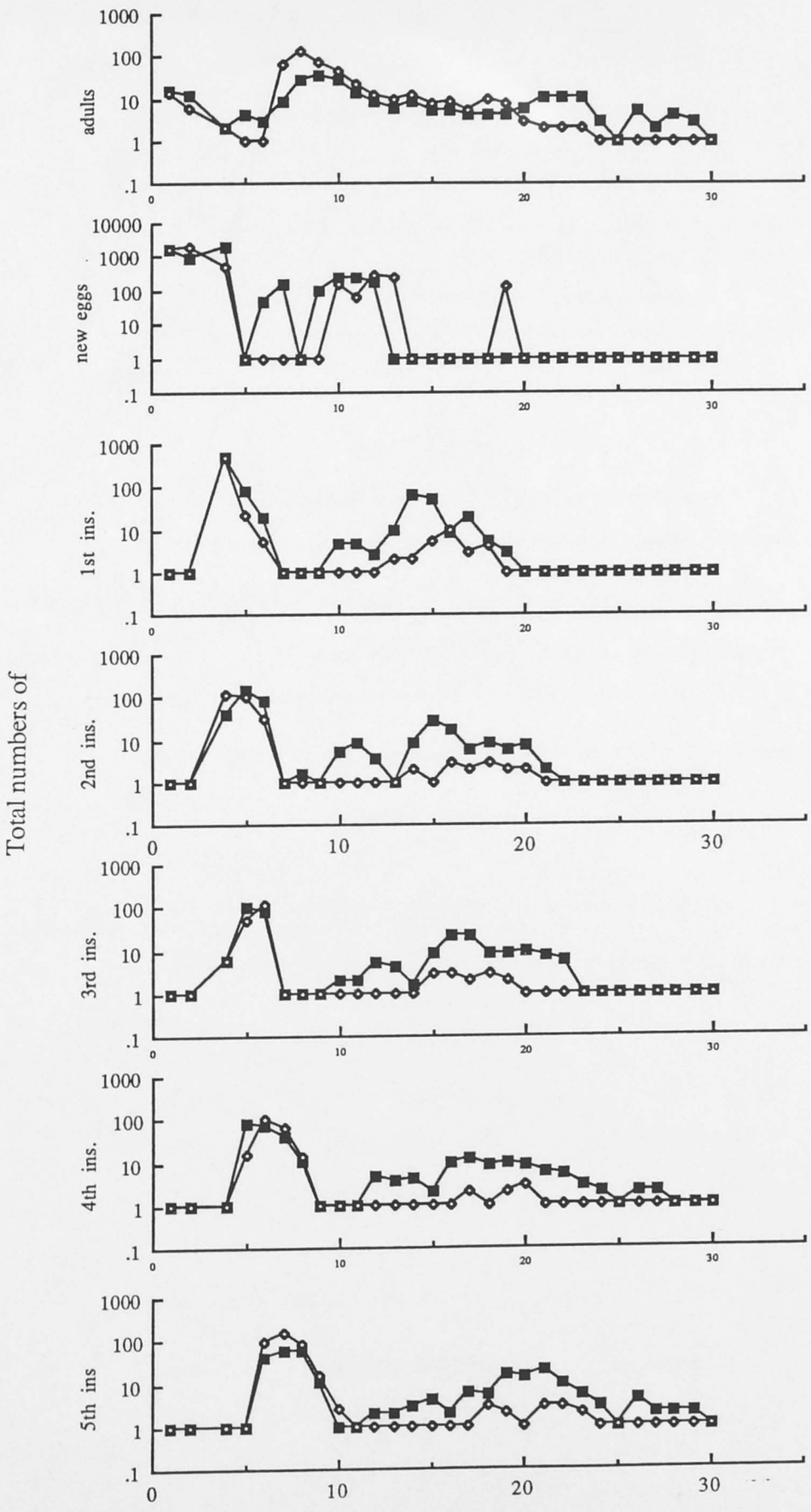
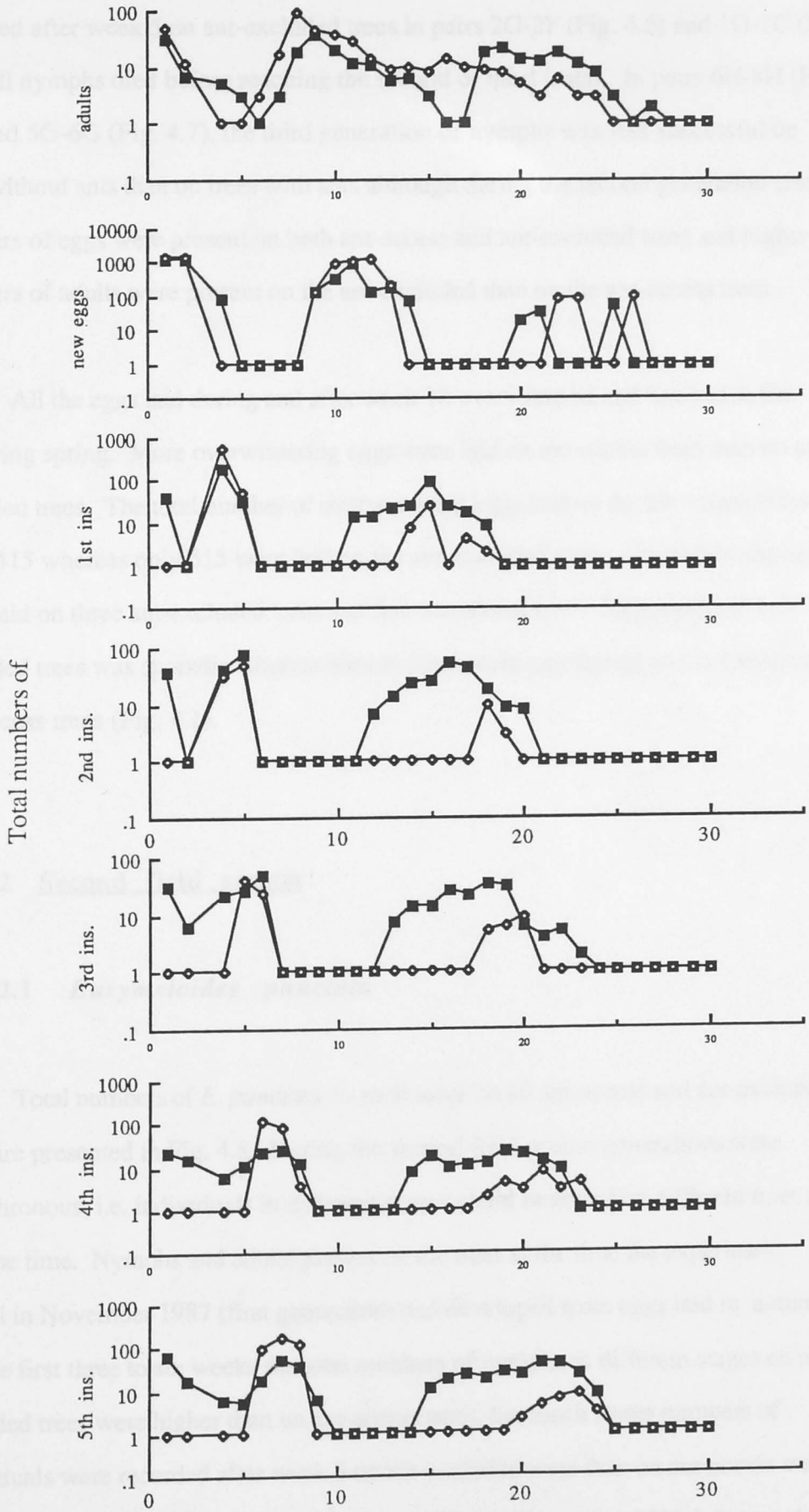

Total numbers of
adults
new eggs
1st ins.
2nd ins.
3rd ins.
4th ins.
5th ins
1000
100
10
1
.1
10000
0
10
20
30
Weeks (from 15 Dec. 1986 - 6 July 1987)

Fig. 4.7

Total numbers of individuals of *E. punctata* in each stage on trees 5G-6G in the first field season (Dec. 1986 - July 1987).

■ = ant-access

◇ = ant-excluded


Total numbers of
adults
new eggs
1st ins
2nd ins.
3rd ins.
4th ins.
5th ins.
100
10
1
.1
1000
10000
0
10
20
30
Weeks (from 15 Dec. 1986 - 6 July 1987)

recorded after week 5 on ant-excluded trees in pairs 2G-2F (Fig. 4.5) and 1G-1C (Fig. 4.3), all nymphs died before reaching the second or third instar. In pairs 6H-8H (Fig. 4.6) and 5G-6G (Fig. 4.7), the third generation of nymphs was less successful on trees without ants than on trees with ants although during the second generation similar numbers of eggs were present on both ant-access and ant-excluded trees and higher numbers of adults were present on the ant-excluded than on the ant-access trees.

All the eggs laid during and after week 18 overwintered and hatched in the following spring. More overwintering eggs were laid on ant-access trees than on ant-excluded trees. The total number of overwintering eggs laid on the ant-access trees was 4415 whereas only 515 were laid on the ant-excluded trees. Overwintering eggs were laid on three ant-excluded trees and five ant-access trees. Egg laying on ant-excluded trees was sporadic whereas almost continuous egg laying was recorded on ant-access trees (Fig. 4.1).

4.3.1.2 Second field season

4.3.1.2.1 *Eurymeloides punctata*

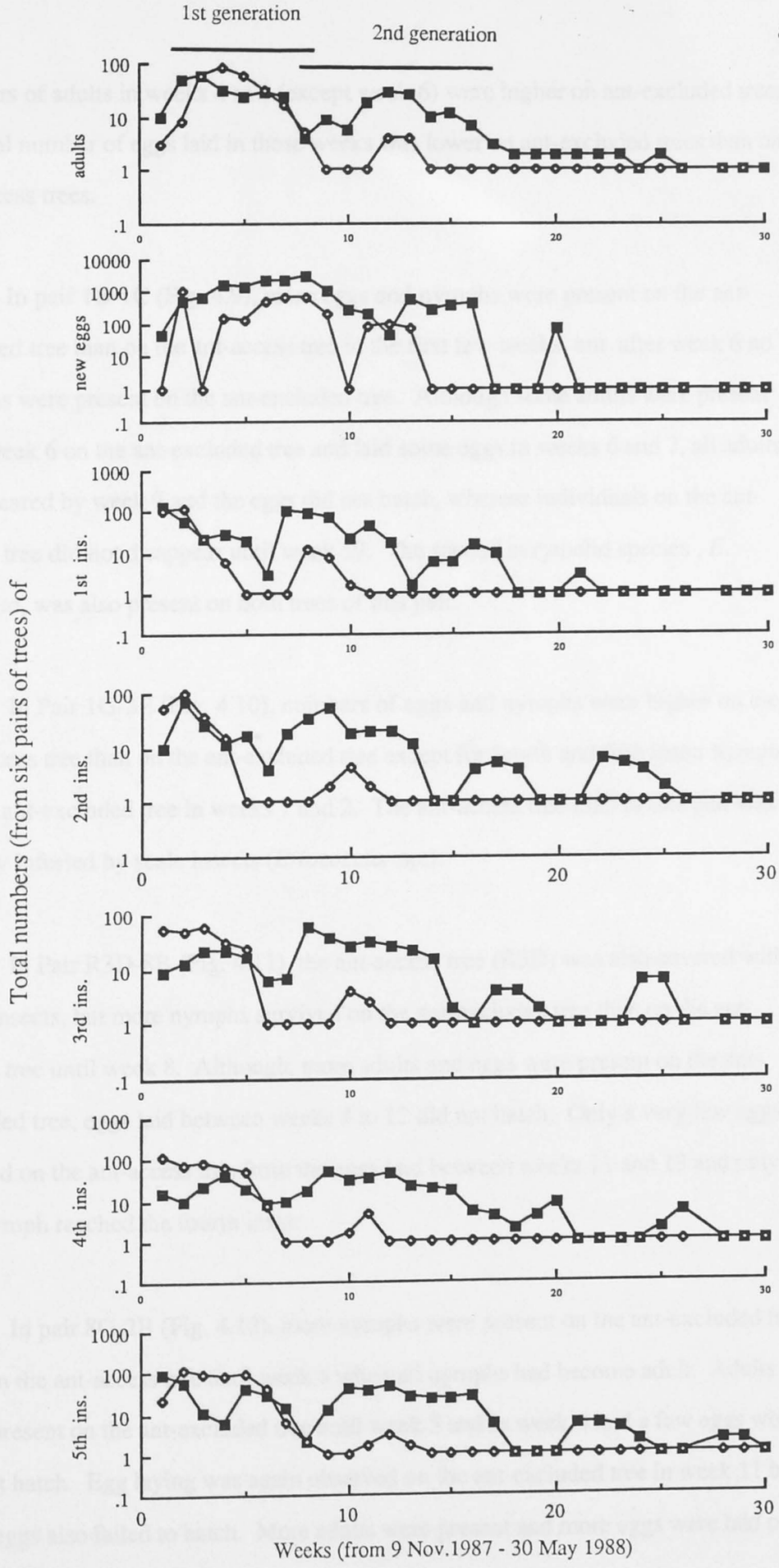
Total numbers of *E. punctata* in each stage on all ant-access and ant-excluded trees are presented in Fig. 4.8. During the second field season generations were asynchronous, i.e. individuals in different stages could be found on different trees at any one time. Nymphs and adults present on the trees at the time the experiment started in November 1987 (first generation) had developed from eggs laid in autumn. For the first three to six weeks the total numbers of nymphs in different stages on ant-excluded trees were higher than on ant-access trees, but much lower numbers of individuals were recorded after week 6 on ant-excluded trees than on ant-access trees. Hatching and survival of nymphs from the eggs laid in December 1987 (after week 6) was much higher on ant-access trees than on ant-excluded trees. Although the total

Fig. 4.8

Total numbers of individuals of *E. punctata* in each stage on six pairs of trees the second field season (Nov. 1987 - June 1988).

■ = ant-access

◆ = ant-excluded


1st generation
2nd generation
adults
new eggs
1st ins.
2nd ins.
3rd ins.
4th ins.
5th ins.
100
10
1
.1
10000
1000
0
10
20
30
Total numbers (from six pairs of trees) of
Weeks (from 9 Nov.1987 - 30 May 1988)

numbers of adults in weeks 4 to 8 (except week 6) were higher on ant-excluded trees , the total number of eggs laid in those weeks was lower on ant-excluded trees than on ant-access trees.

In pair 1B-1C (Fig. 4.9), more eggs and nymphs were present on the ant-excluded tree than on the ant-access tree in the first few weeks, but after week 6 no nymphs were present on the ant-excluded tree. Although some adults were present after week 6 on the ant-excluded tree and laid some eggs in weeks 6 and 7, all adults disappeared by week 9 and the eggs did not hatch, whereas individuals on the ant-access tree did not disappear until week 19. The second eurymelid species , *E. distincta*, was also present on both trees of this pair.

In Pair 1G-3E (Fig. 4.10), numbers of eggs and nymphs were higher on the ant-access tree than on the ant-excluded tree except for fourth and fifth instar nymphs on the ant-excluded tree in weeks 1 and 2. The ant-access tree (3E) of this pair was heavily infested by scale insects (*Eriococcus* sp.).

In Pair R3D-8B (Fig. 4.11), the ant-access tree (R3D) was also covered with scale insects, but more nymphs survived on the ant-excluded tree than on the ant-access tree until week 8. Although, more adults and eggs were present on the ant-excluded tree, eggs laid between weeks 4 to 12 did not hatch. Only a very few eggs hatched on the ant-access tree from the eggs laid between weeks 11 and 13 and only one nymph reached the fourth instar.

In pair 8G-2B (Fig. 4.12), more nymphs were present on the ant-excluded tree than on the ant-access tree until week 4 when all nymphs had become adult. Adults were present on the ant-excluded tree until week 5 and in week 6 laid a few eggs which did not hatch. Egg laying was again observed on the ant-excluded tree in week 11 but these eggs also failed to hatch. More adults were present and more eggs were laid on

Fig. 4.9

Total numbers of individuals of *E. punctata* in each stage on trees 1B-1C in the second field season (Nov. 1987 - June 1988).

■ = ant-access

◆ = ant-excluded

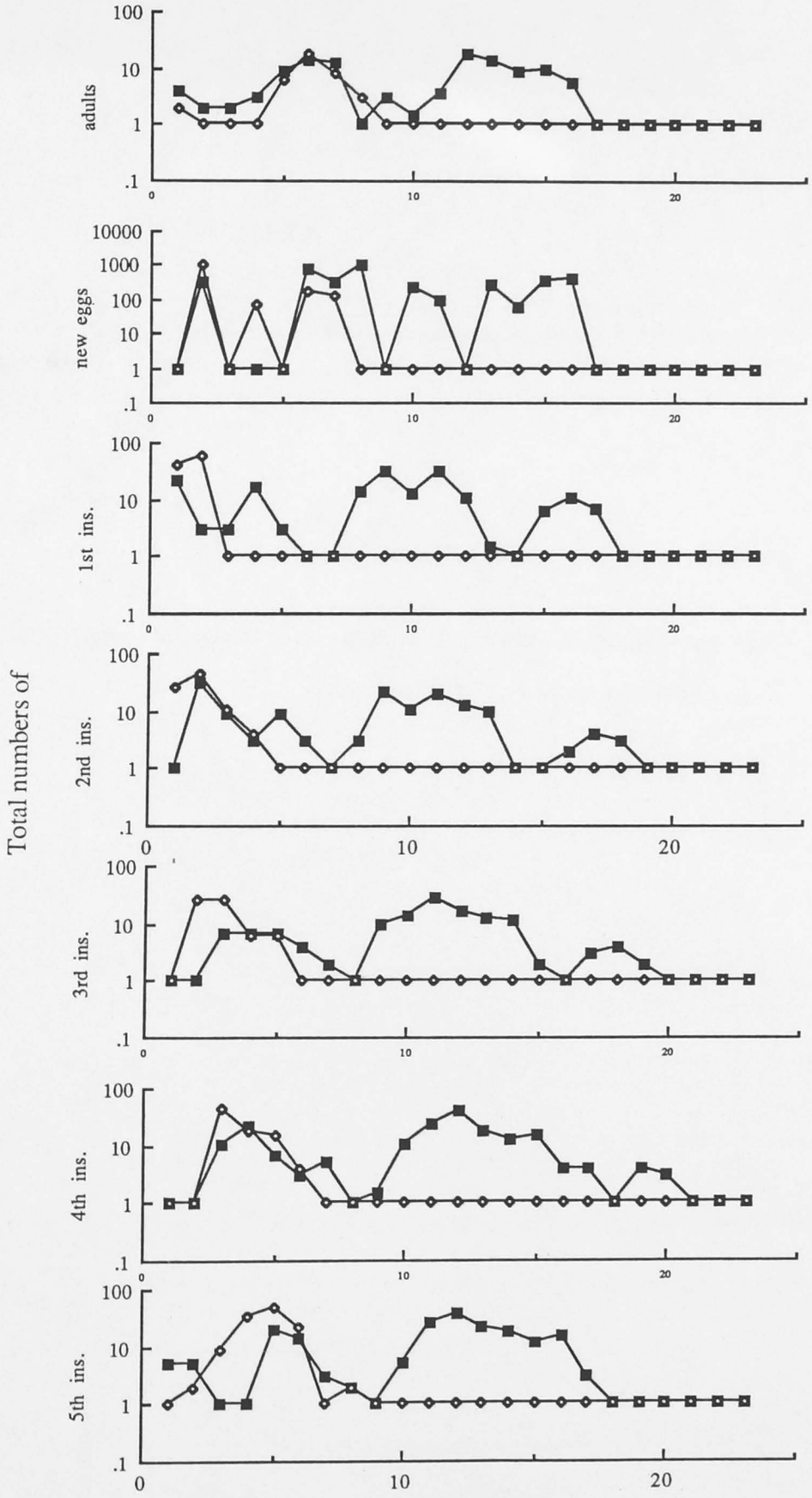

Total numbers of
adults
new eggs
1st ins.
2nd ins.
3rd ins.
4th ins.
5th ins.
100
10
1
.1
10000
1000
0
10
20
Weeks (from 9 Nov.1987 - 18 Apr. 1988)

Fig. 4.10

Total numbers of individuals of *E. punctata* in each stage on trees 1G-3E in the second field season (Nov. 1987 - June 1988).

■ = ant-access

◇ = ant-excluded

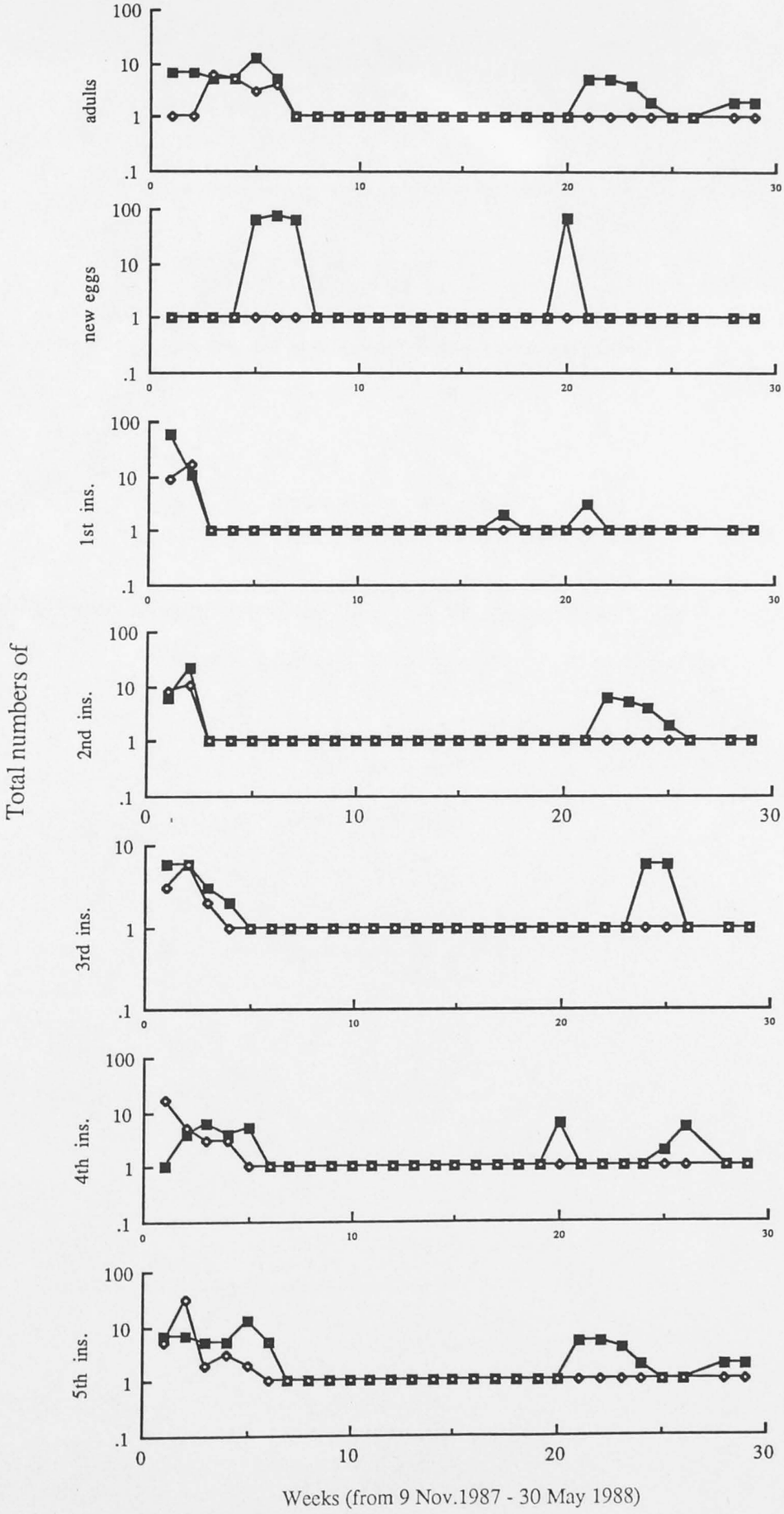

Total numbers of
adults
new eggs
1st ins.
2nd ins.
3rd ins.
4th ins.
5th ins.
100
10
1
.1
0
10
20
30
Weeks (from 9 Nov.1987 - 30 May 1988)

Fig. 4.11

Total numbers of individuals of *E. punctata* in each stage on trees R3D-8B in the second field season (Nov. 1987 - June 1988).

■ = ant-access

◆ = ant-excluded

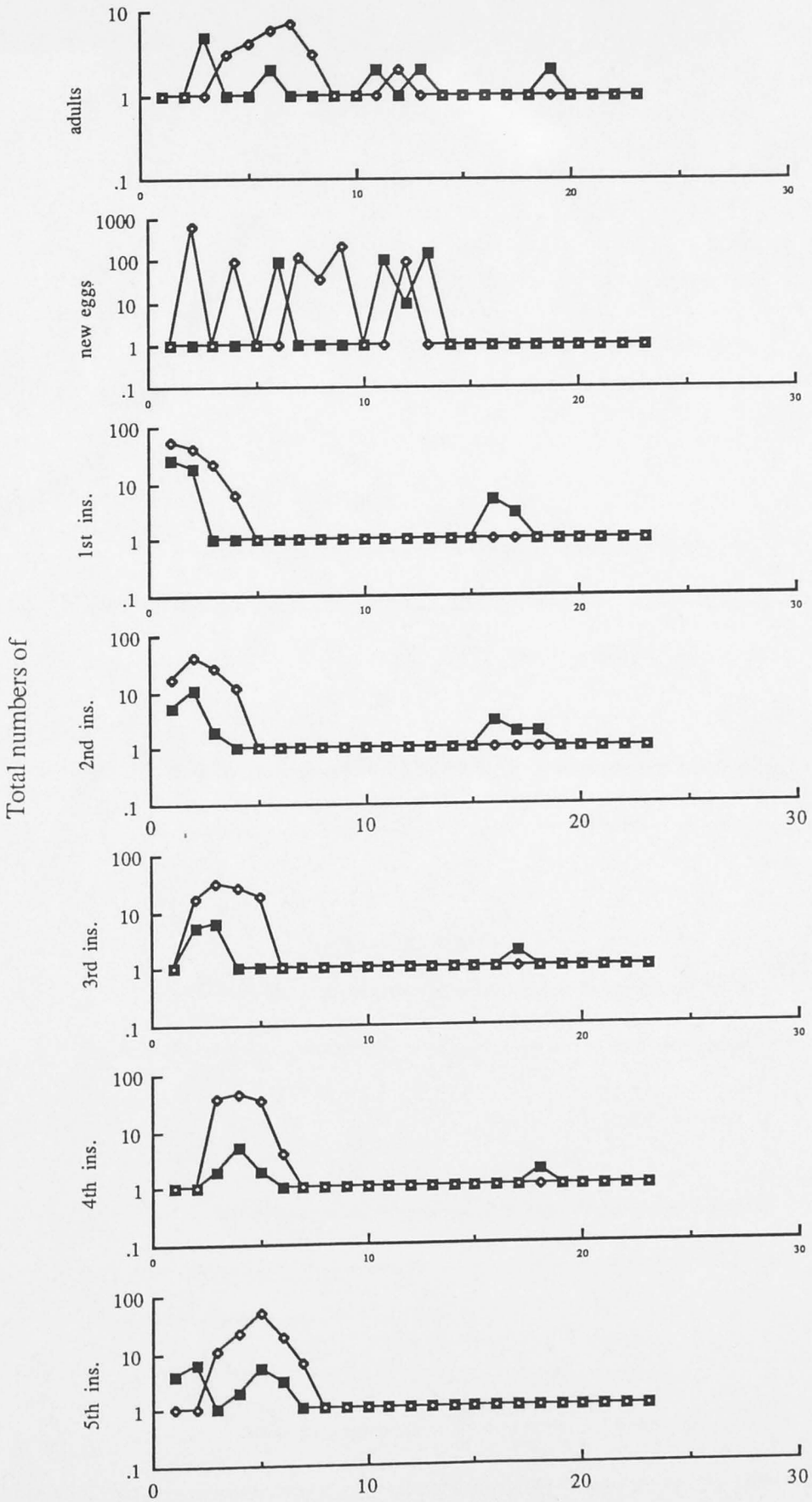

Total numbers of
adults
new eggs
1st ins.
2nd ins.
3rd ins.
4th ins.
5th ins.
10
1
.1
1000
100
0
10
20
30
Weeks (from 9 Nov.1987 - 18 Apr. 1988)

Fig. 4.12

Total numbers of individuals of *E. punctata* in each stage on trees 8G-2B in the second field season (Nov. 1987 - June 1988).

■ = ant-access

◇ = ant-excluded

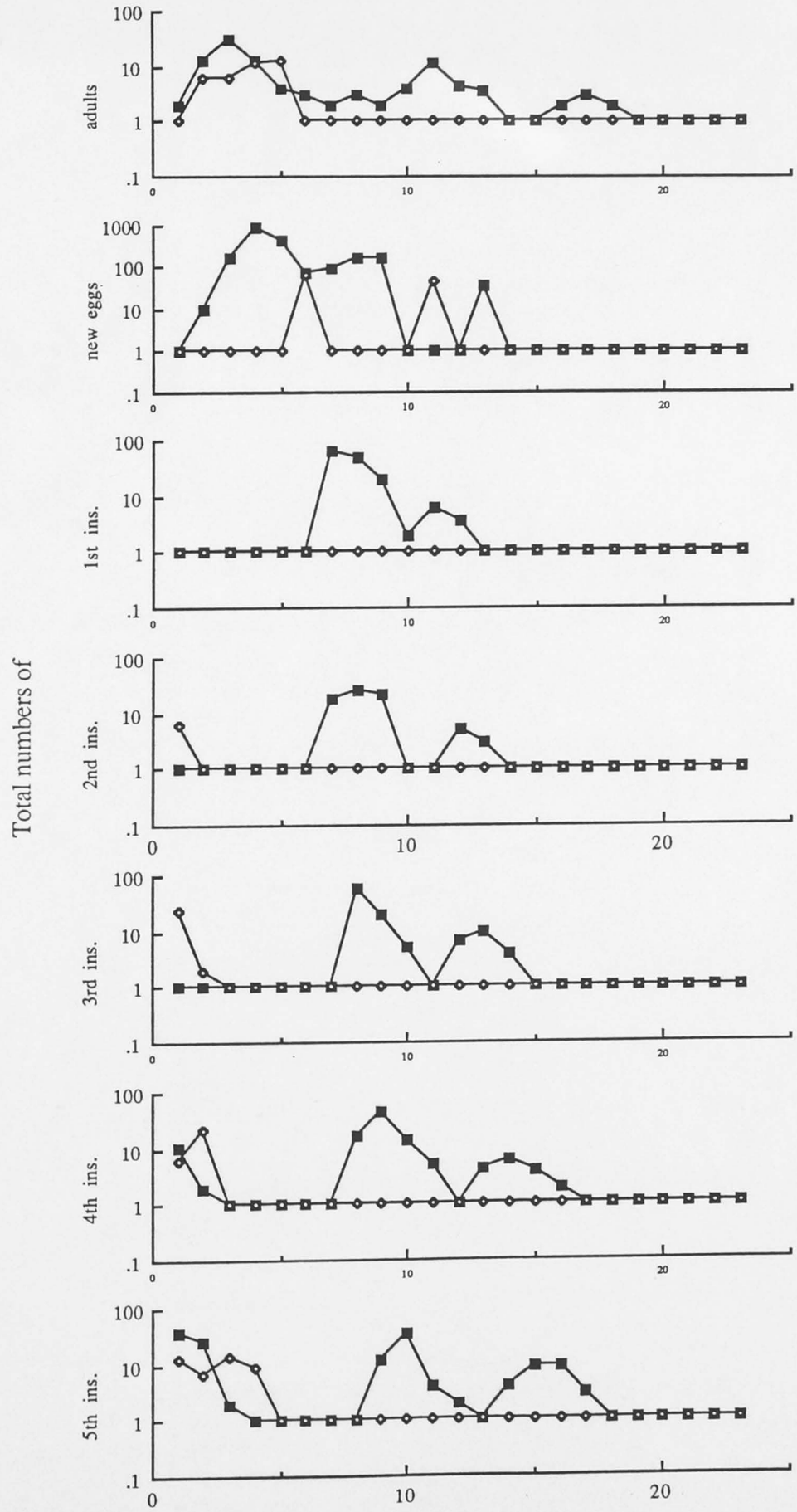

Total numbers of
adults
new eggs
1st ins.
2nd ins.
3rd ins.
4th ins.
5th ins.
100
10
1
.1
1000
0
10
20
Weeks (from 9 Nov.1987 - 18 Apr. 1988)

Fig. 4.13

Total numbers of individuals of *E. punctata* in each stage on trees 3A-7A in the second field season (Nov. 1987 - June 1988).

■ = ant-access

◇ = ant-excluded

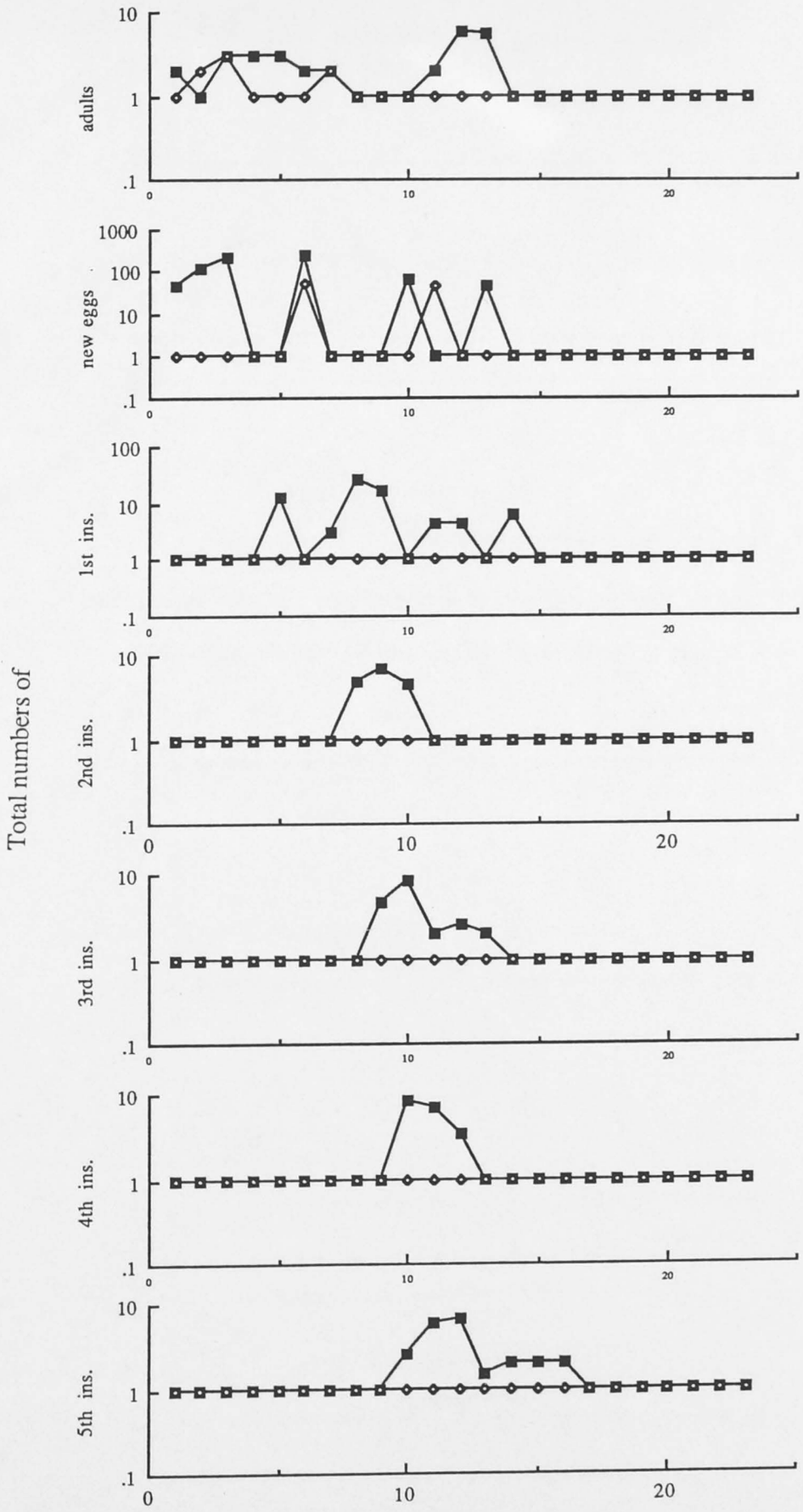
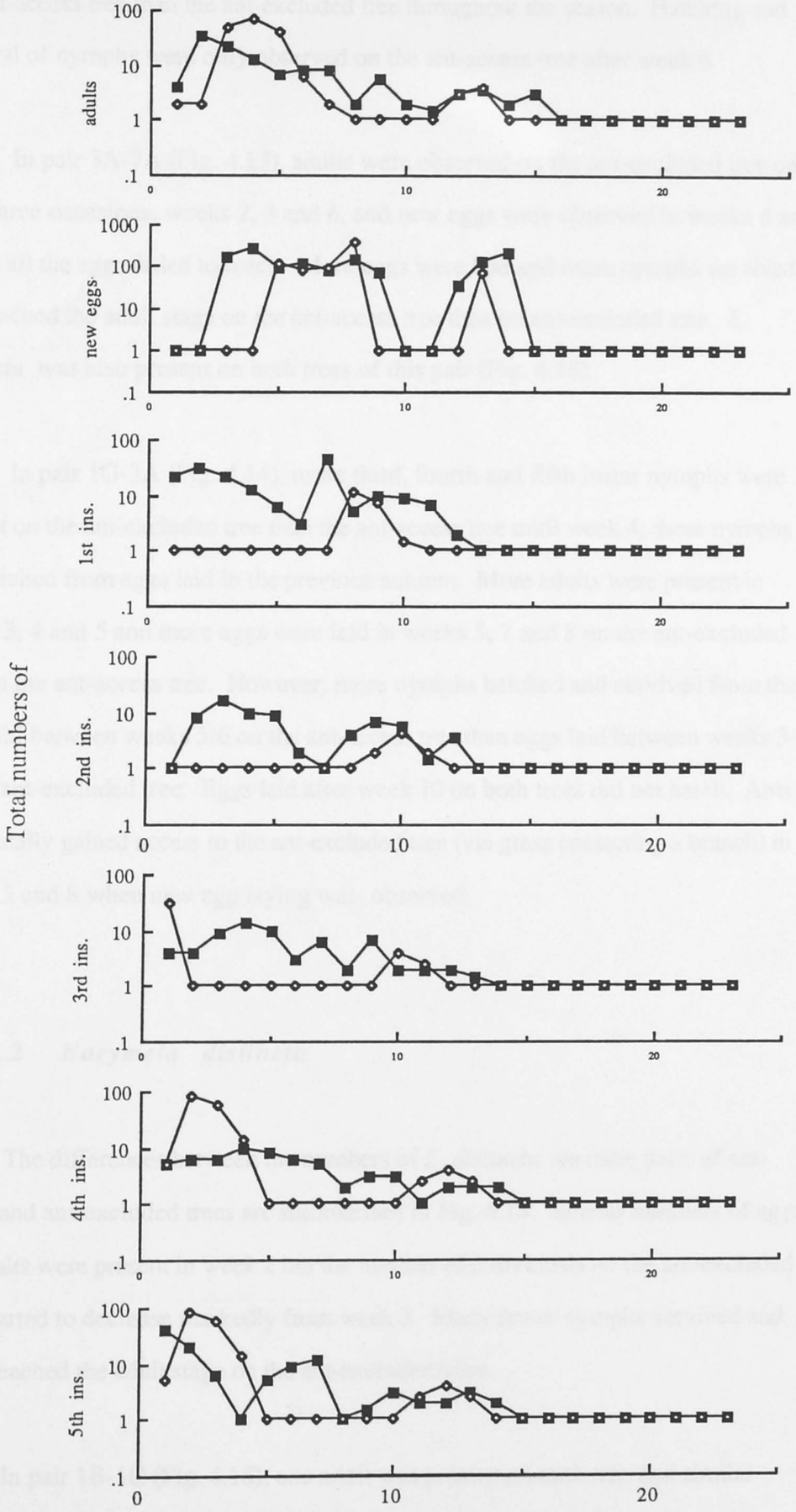

Total numbers of
adults
new eggs
1st ins.
2nd ins.
3rd ins.
4th ins.
5th ins.
10
1
.1
1000
100
0
10
20
Weeks (from 9 Nov.1987 - 18 Apr. 1988)

Fig. 4.14

Total numbers of individuals of *E. punctata* in each stage on trees 1G-3A (block-B) in the second field season (Nov. 1987 - June 1988).

■ = ant-access

◆ = ant-excluded


Total numbers of
adults
new eggs
1st ins.
2nd ins.
3rd ins.
4th ins.
5th ins.
100
10
1
.1
1000
0
10
20
Weeks (from 9 Nov.1987 - 18 Apr. 1988)

the ant-access tree than the ant-excluded tree throughout the season. Hatching and survival of nymphs were only observed on the ant-access tree after week 6.

In pair 3A-7A (Fig. 4.13), adults were observed on the ant-excluded tree on only three occasions, weeks 2, 3 and 6, and new eggs were observed in weeks 6 and 11 but all the eggs failed to hatch. More eggs were laid and more nymphs survived and reached the adult stage on the ant-access tree than on ant-excluded tree. *E. distincta* was also present on both trees of this pair (Fig. 4.18).

In pair 1G-3A (Fig. 4.14), more third, fourth and fifth instar nymphs were present on the ant-excluded tree than the ant-access tree until week 4; these nymphs had hatched from eggs laid in the previous autumn. More adults were present in weeks 3, 4 and 5 and more eggs were laid in weeks 5, 7 and 8 on the ant-excluded than on the ant-access tree. However, more nymphs hatched and survived from the eggs laid between weeks 5-6 on the ant-access tree than eggs laid between weeks 3-9 on the ant-excluded tree. Eggs laid after week 10 on both trees did not hatch. Ants accidentally gained access to the ant-excluded tree (via grass contacting a branch) in weeks 5 and 8 when new egg laying was observed.

4.3.1.2.2 *Eurymela distincta*

The differences between the numbers of *E. distincta* on three pairs of ant-access and ant-excluded trees are summarised in Fig. 4.15. Similar numbers of eggs and adults were present in week 2 but the number of individuals on the ant-excluded trees started to decrease markedly from week 3. Many fewer nymphs survived and fewer reached the adult stage on the ant-excluded trees.

In pair 1B-1C (Fig. 4.16), one adult was present on each tree and similar numbers of eggs were observed on both trees during week 2 but the adult on the ant-

Fig. 4.15

Total numbers of individuals of *E. distincta* in each stage on three pairs of trees in the second field season (Nov. 1987 - June 1988).

■ = ant-access

◇ = ant-excluded

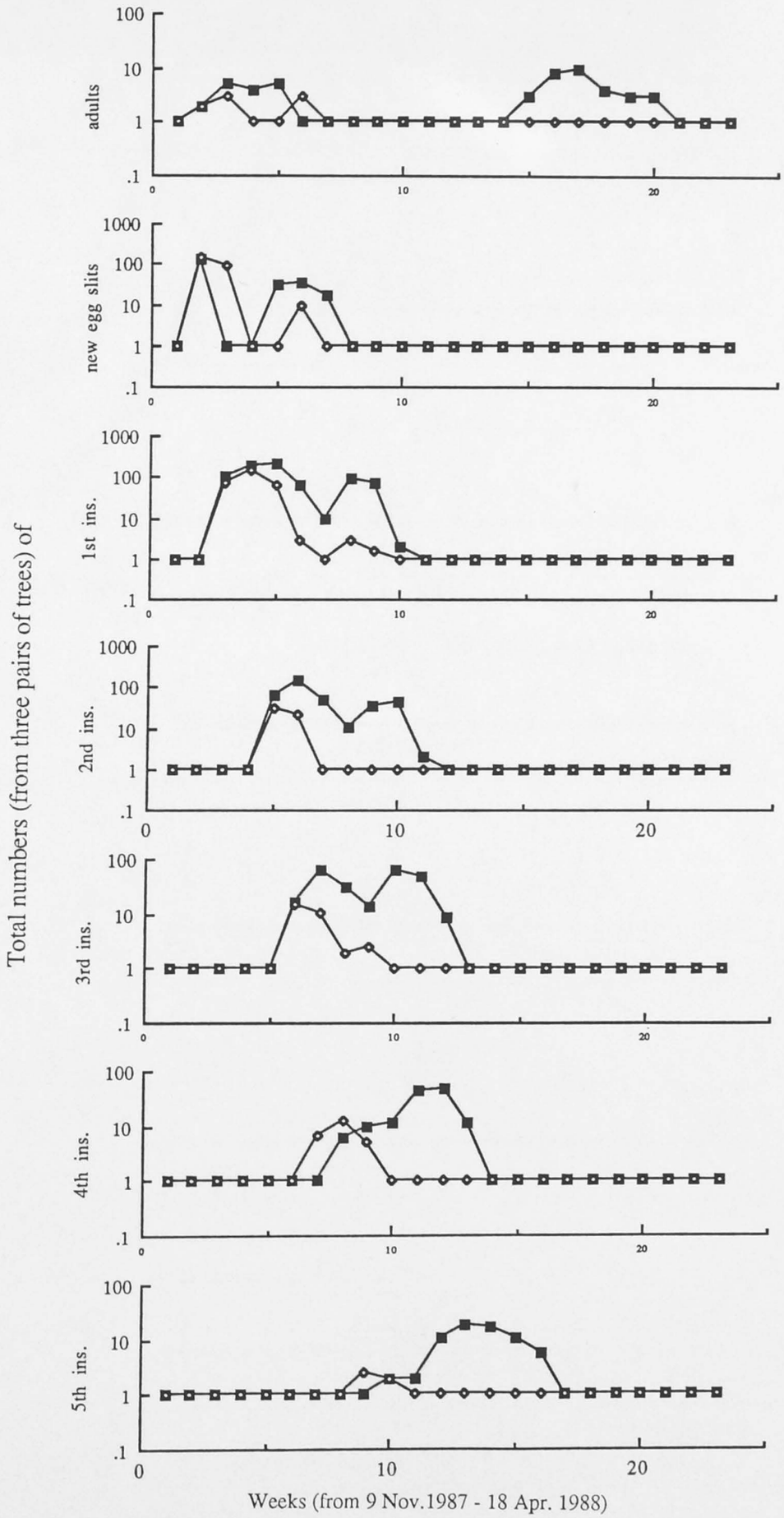
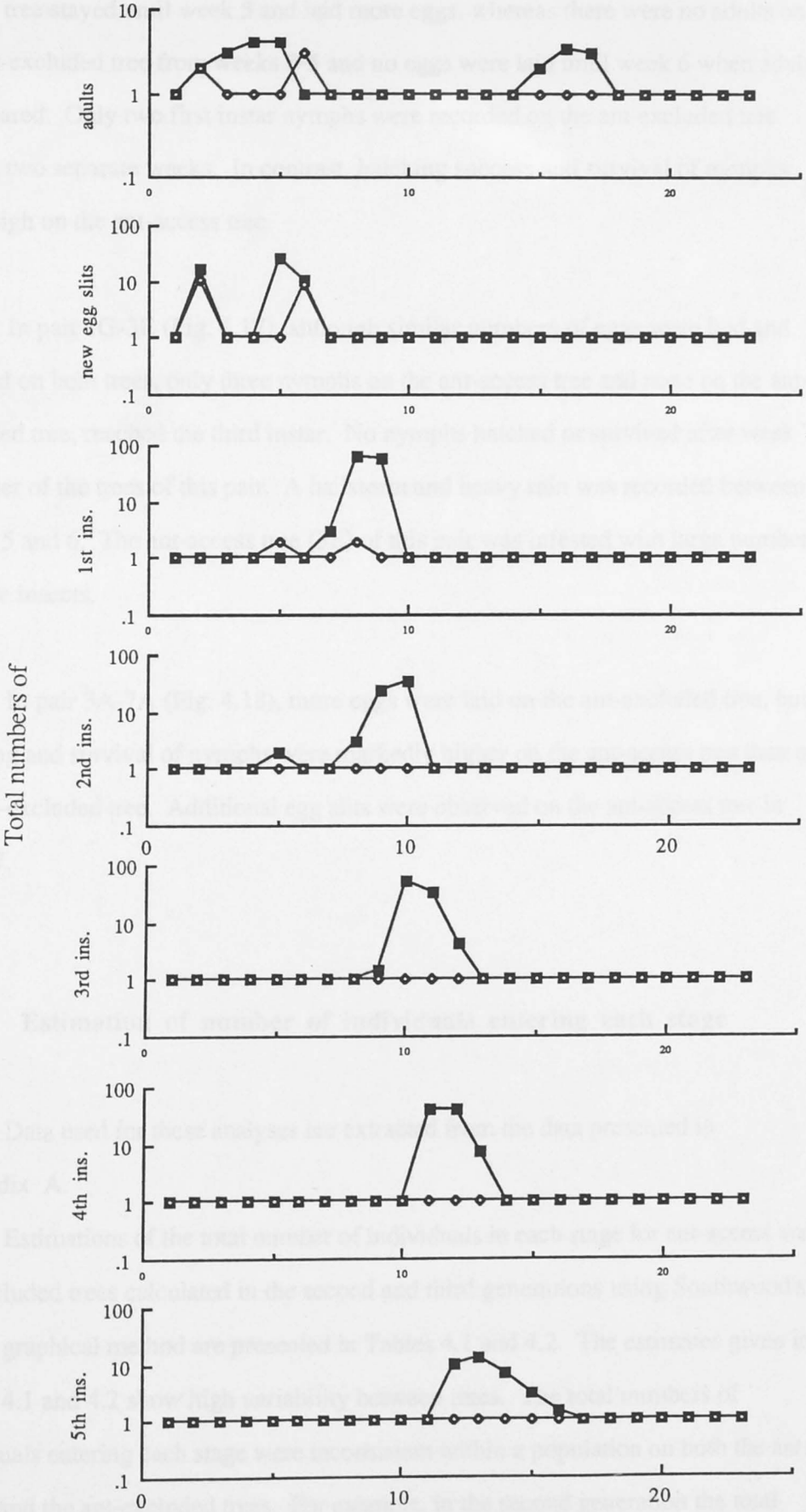

Total numbers (from three pairs of trees) of
adults
new egg slits
1st ins.
2nd ins.
3rd ins.
4th ins.
5th ins.
100
10
1
.1
1000
0
10
20
Weeks (from 9 Nov.1987 - 18 Apr. 1988)

Fig. 4.16

Total numbers of individuals of *E. distincta* in each stage on trees 1B-1C in the second field season (Nov. 1987 - June 1988).

■ = ant-access

◆ = ant-excluded


Total numbers of
adults
new egg slits
1st ins.
2nd ins.
3rd ins.
4th ins.
5th ins.
10
1
.1
100
0
10
20
Weeks (from 9 Nov.1987 - 18 Apr. 1988)

access tree stayed until week 5 and laid more eggs, whereas there were no adults on the ant-excluded tree from weeks 3-5 and no eggs were laid until week 6 when adults reappeared. Only two first instar nymphs were recorded on the ant-excluded tree during two separate weeks. In contrast, hatching success and survival of nymphs were high on the ant-access tree.

In pair 1G-3E (Fig. 4.17), although similar numbers of eggs were laid and hatched on both trees, only three nymphs on the ant-access tree and none on the ant-excluded tree, reached the third instar. No nymphs hatched or survived after week 7 on either of the trees of this pair. A hailstorm and heavy rain was recorded between weeks 5 and 6. The ant-access tree (3E) of this pair was infested with large numbers of scale insects.

In pair 3A-7A (Fig. 4.18), more eggs were laid on the ant-excluded tree, but hatching and survival of nymphs were markedly higher on the ant-access tree than on the ant-excluded tree. Additional egg slits were observed on the ant-access tree in week 7.

4.3.2 Estimation of number of individuals entering each stage

Data used for these analyses are extracted from the data presented in Appendix A.

Estimations of the total number of individuals in each stage for ant-access and ant-excluded trees calculated in the second and third generations using Southwood's (1978) graphical method are presented in Tables 4.1 and 4.2. The estimates given in Tables 4.1 and 4.2 show high variability between trees. The total numbers of individuals entering each stage were inconsistent within a population on both the ant-access and the ant-excluded trees. For example, in the second generation the total numbers of individuals were higher in fourth instar than in third instar on trees, 1G,

Fig. 4.17

Total numbers of individuals of *E. distincta* in each stage on trees 1G-3E in the second field season (Nov. 1987 - June 1988).

■ = ant-access

◆ = ant-excluded

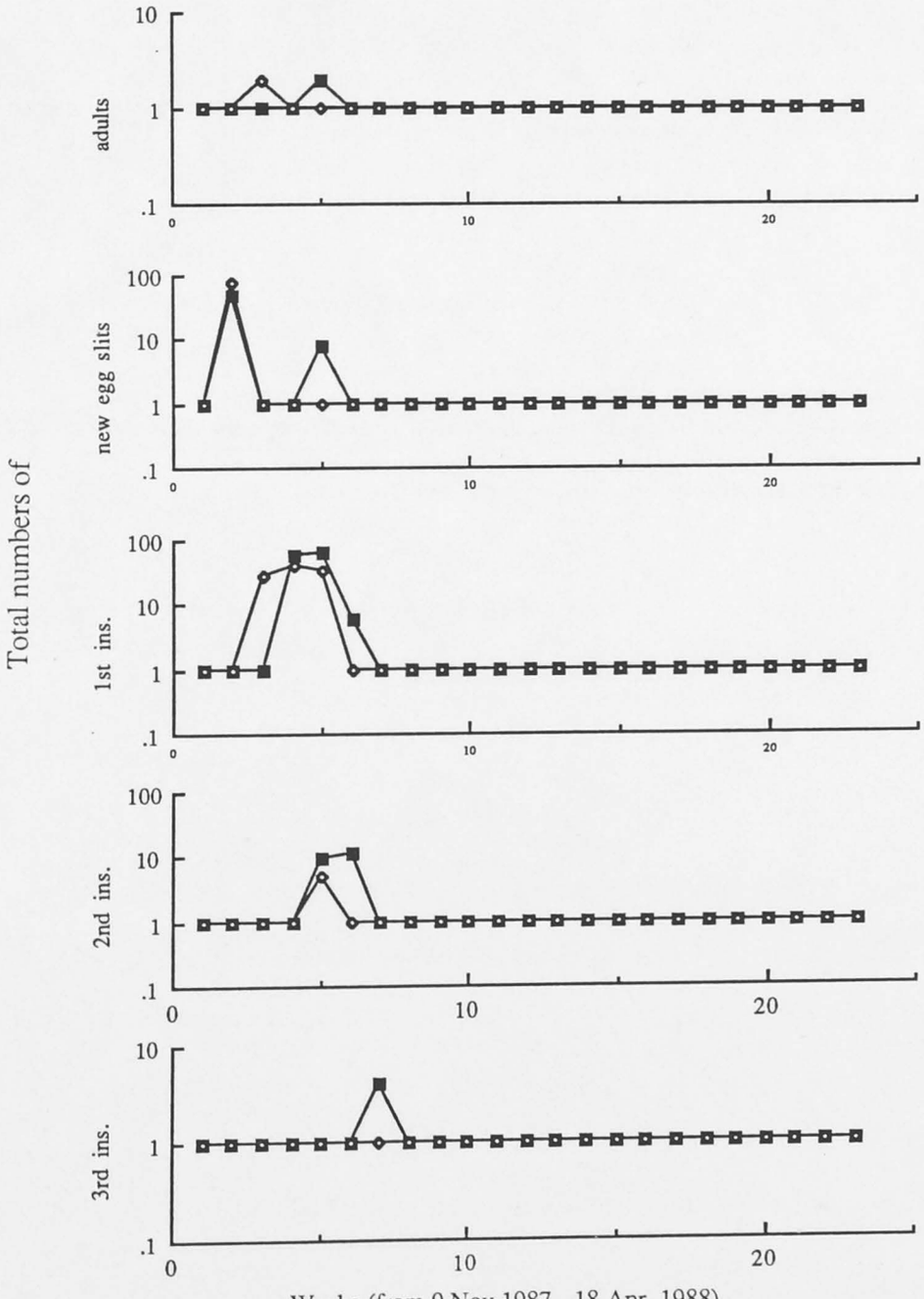
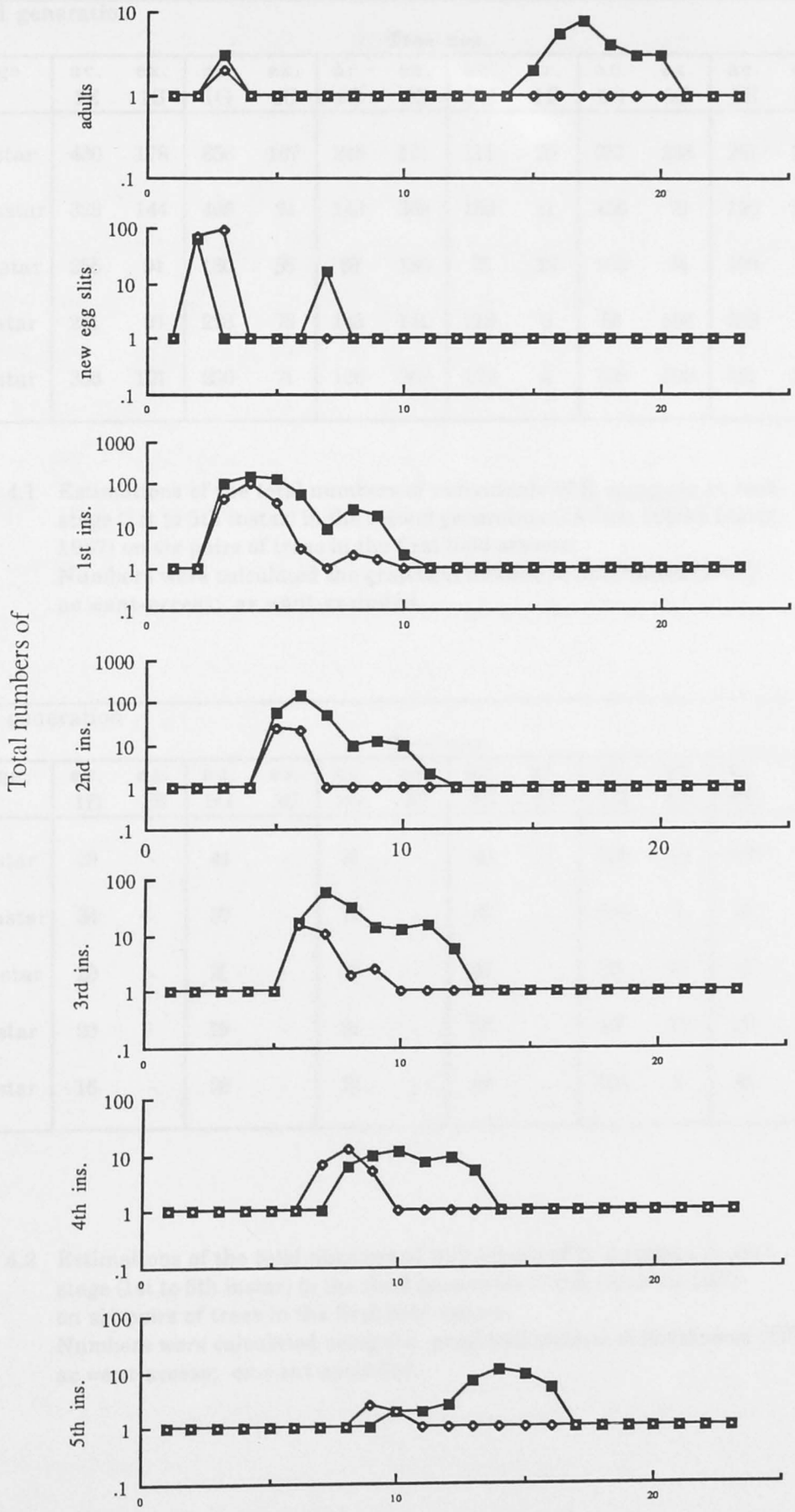

Total numbers of
adults
new egg slits
1st ins.
2nd ins.
3rd ins.
10
1
.1
100
0
10
20
Weeks (from 9 Nov.1987 - 18 Apr. 1988)

Fig. 4.18

Total numbers of individuals of *E. distincta* in each stage on trees 3A-7A in the second field season (Nov. 1987 - June 1988).

■ = ant-access

◆ = ant-excluded


Total numbers of
adults
new egg slits
1st ins.
2nd ins.
3rd ins.
4th ins.
5th ins.
10
1
.1
100
1000
0
10
20
Weeks (from 9 Nov.1987 - 18 Apr. 1988)

second generation	Tree nos.											
Stage	ac. 1E	ex. 1B	ac. 1G	ex. 1C	ac. 2G	ex. 2F	ac. 3H	ex. 1F	ac. 5G	ex. 6G	ac. 6H	ex. 8H
1st instar	430	178	856	107	246	171	111	25	381	238	261	181
2nd instar	328	144	405	94	143	289	152	11	136	79	190	193
3rd instar	255	94	180	38	88	186	75	12	109	74	193	-5
4th instar	241	69	228	76	143	141	118	0	56	156	253	87
5th instar	336	101	230	71	106	269	172	4	109	300	121	357

Table 4.1 Estimations of the total numbers of individuals of E. punctata in each stage (1st to 5th instar) in the second generation (15 Dec. 1986-9 March 1987) on six pairs of trees in the first field season.
Numbers were calculated the graphical method of Southwood (1978).
ac.=ant-access; ex.=ant-excluded.

Third generation	Tree nos.											
Stage	ac. 1E	ex. 1B	ac. 1G	ex. 1C	ac. 2G	ex. 2F	ac. 3H	ex. 1F	ac. 5G	ex 6G	ac. 6H	ex. 8H
1st instar	59	-	44	-	31	-	49	-	125	20	100	11
2nd instar	34	-	37	-	12	-	37	-	110	7	47	5
3rd instar	20	-	21	-	17	-	29	-	92	11	47	5
4th instar	20	-	19	-	24	-	33	-	67	11	32	2
5th instar	16	-	26	-	13	-	40	-	118	9	43	5

Table 4.2 Estimations of the total numbers of individuals of E. punctata in each stage (1st to 5th instar) in the third generation (9 Feb.-29 June 1987) on six pairs of trees in the first field season.
Numbers were calculated using the graphical method of Southwood (1978).
ac.=ant-access; ex.=ant-excluded.

1C, 2G, 3H, 6G, 6H and 8H. Similarly, the total numbers of individuals were higher in fifth instar than in fourth instar on the most of the trees in the second and the third generations.

The estimated total numbers of individuals surviving in each stage on the ant-access and ant-excluded trees in the second and third generations using Farrow's method (see section 3.2.6 in Chapter 3) are presented in Table 4.3 and in Table 4.4 respectively. The percentage survival in each stage in the second and third generations on the ant-access and the ant-excluded trees are presented in Figs 4.19 and 4.20 respectively. The difference in the percentage survival on the ant-access and the ant-excluded trees was not remarkable in the second generation (Fig. 4.19) but the negative effect of ant exclusion was very clear in the third generation (Fig. 4.20). In the second generation from 23 to 82% survival was recorded from eggs to first instar on the ant-access trees and from 13 to 70% on the ant-excluded trees. Three to 21% survival was recorded from eggs to fifth instar in the second generation on ant-access trees and only 0.1 to 9% on the ant-excluded trees.

In the third generation (Table 4.4 and Fig. 4.20), survival from eggs to first instar varied from 8 to 13% on the ant-access trees and 0.3 to 15% on the ant-excluded trees. However, no eggs were laid on ant-excluded tree 1B and on ant-excluded trees 1C, 1F and 2F nymphs failed to reach second or third instar. From 0.4 to 6% survival from eggs to fifth instar in the third generation was recorded on six ant-access trees whereas, only 0.2 to 0.5% survived on two trees.

4.3.3 Average population age

The average population age of nymphs on each pair of trees on successive days is plotted and presented in Fig. 4.21. There are no significant differences between the average population age of individuals on ant-access and ant-excluded trees (Table 4.5).

Table 4.3

Total numbers of individuals survived in each stage of *E. punctata* in the second generation on six pairs of ant-access and ant-excluded trees calculated by using Farrow's method described in Chapter 3, in section 3.2.6. Total numbers of individuals in each stage taken from weekly counts are presented on the left hand side of each column (n_1) and corrected numbers of the same on the right (n2) for each tree.

Paired trees : 1E-1B; 1G-1C; 2G-2F; 3H-1F; 5G-6G; 6H-8H.

SECOND GENERATION

Ant-access trees												
Stages	Trees											
	1E		1G		2G		3H		5G		6H	
	n1	n2	n1	n2	n1	n2	n1	n2	n1	n2	n1	n2
Eggs	1475	-	2344	-	2344	-	521	-	2691	-	4427	-
1st ins.	522	1218	499	1164	240	560	98	228	262	611	558	1302
2nd ins.	364	637	424	742	130	228	111	194	150	263	272	476
3rd ins.	278	389	347	486	114	160	104	146	130	182	183	256
4th ins.	231	231	287	287	156	156	109	109	107	107	203	203
5th ins.	384	269	223	156	112	78	160	112	190	133	160	112

Ant-excluded trees												
Stages	Trees											
	1B		1C		2F		1F		6G		8H	
	n1	n2	n1	n2	n1	n2	n1	n2	n1	n2	n1	n2
Eggs	1302	-	1736	-	2604	-	782	-	2778	-	3993	-
1st ins.	392	915	408	952	235	548	45	105	575	1341	524	1223
2nd ins.	218	382	133	233	260	455	19	33	80	140	243	425
3rd ins.	118	165	78	109	199	279	12	17	63	88	173	242
4th ins.	66	66	48	48	158	158	6	6	198	198	193	193
5th ins.	102	71	70	49	277	193	2	1	358	251	336	235

Table 4.3

Table 4.4

Total numbers of individuals survived in each stage of *E. punctata* in the third generation on six pairs of ant-access and ant-excluded trees calculated by using Farrow's method described in Chapter 3, in section 3.2.6. Total numbers of individuals in each stage taken from weekly counts are presented on the left hand side of each column (n_1) and corrected numbers of the same on the right (n2) for each tree.

Paired trees : 1E-1B; 1G-1C; 2G-2F; 3H-1F; 5G-6G; 6H-8H.

THIRD GENERATION

Ant-access trees												
Stages	Trees											
	1E		1G		2G		3H		5G		6H	
	n1	n2	n1	n2	n1	n2	n1	n2	n1	n2	n1	n2
Eggs	1311	-	780	-	2603	-	894	-	1719	-	780	-
1st ins.	105	105	84	84	55	55	73	73	212	212	99	99
2nd ins.	57	50	67	59	21	18	66	58	197	172	87	76
3rd ins.	36	25	41	29	31	22	53	37	153	107	93	65
4th ins.	34	20	31	18	43	25	58	34	112	65	73	43
5th ins.	33	15	43	20	24	11	69	32	212	98	82	38
Ant-excluded trees												
Stages	Trees											
	1B		1C		2F		1F		6G		8H	
	n1	n2	n1	n2	n1	n2	n1	n2	n1	n2	n1	n2
Eggs	0	-	86	-	721	-	130	-	3507	-	730	-
1st ins.	0	-	13	13	2	2	8	8	35	35	19	19
2nd ins.	0	-	0	0	0	0	2	2	11	10	8	7
3rd ins.	0	-	0	0	0	0	0	0	17	12	8	6
4th ins.	0	-	0	0	0	0	0	0	17	10	4	2
5th ins.	0	-	0	0	0	0	0	0	17	8	8	4

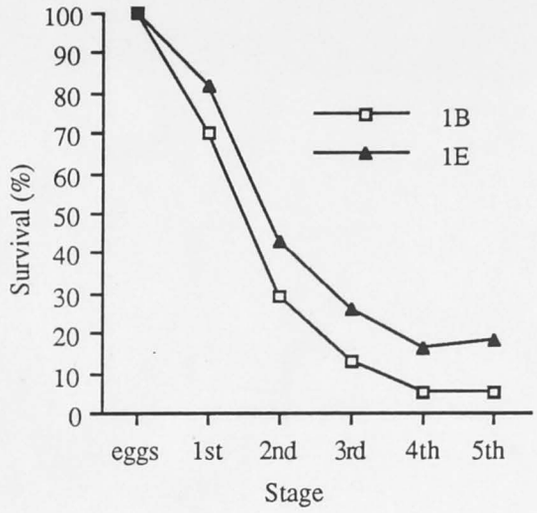
Table 4.4

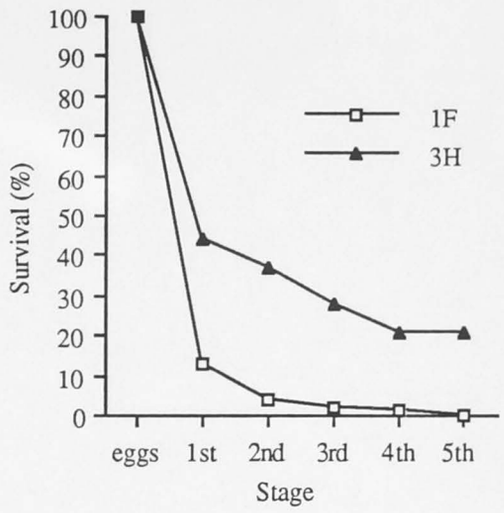
Fig. 4.19

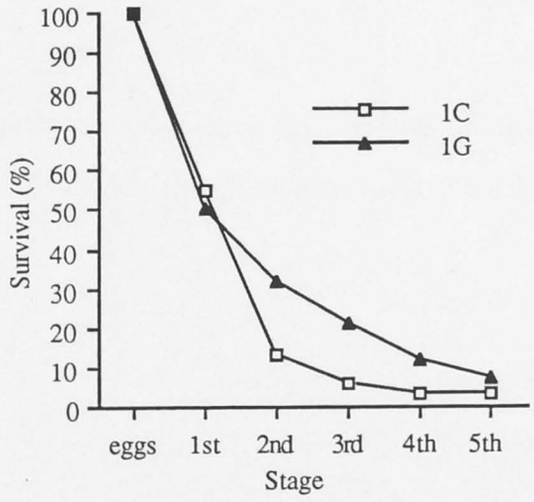
Percentage survival of individuals of *E. punctata* in each stage (eggs to 5th instar) in the second generation (15 December 1986 to 9 March 1987) on six pairs of ant-access and ant-excluded trees.

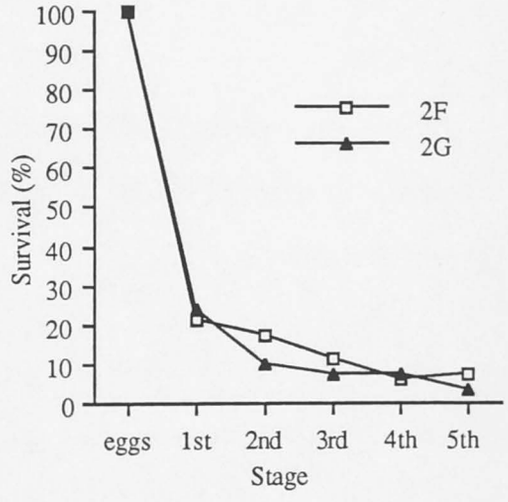
▲ = ant-access

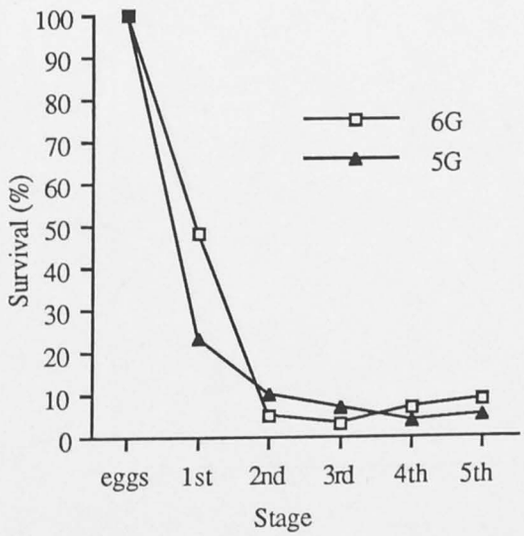
□=ant-excluded


Survival (%)
100
90
80
70
60
50
40
30
20
10
0
1B
1E
eggs
1st
2nd
3rd
4th
5th
Stage


Survival (%)
100
90
80
70
60
50
40
30
20
10
0
1F
3H
eggs
1st
2nd
3rd
4th
5th
Stage


Survival (%)
100
90
80
70
60
50
40
30
20
10
0
1C
1G
eggs
1st
2nd
3rd
4th
5th
Stage


Survival (%)
100
90
80
70
60
50
40
30
20
10
0
2F
2G
eggs
1st
2nd
3rd
4th
5th
Stage


Survival (%)
100
90
80
70
60
50
40
30
20
10
0
6G
5G
eggs
1st
2nd
3rd
4th
5th
Stage

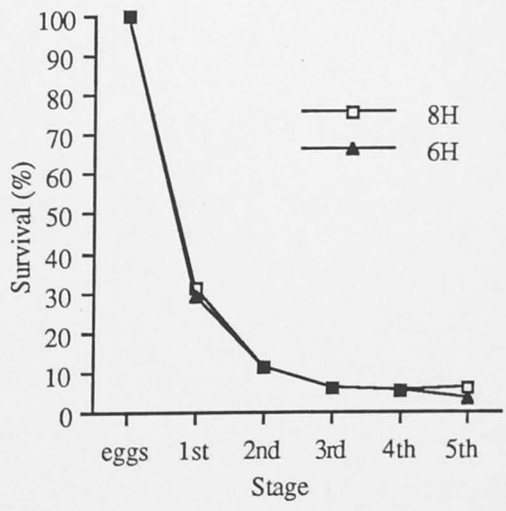
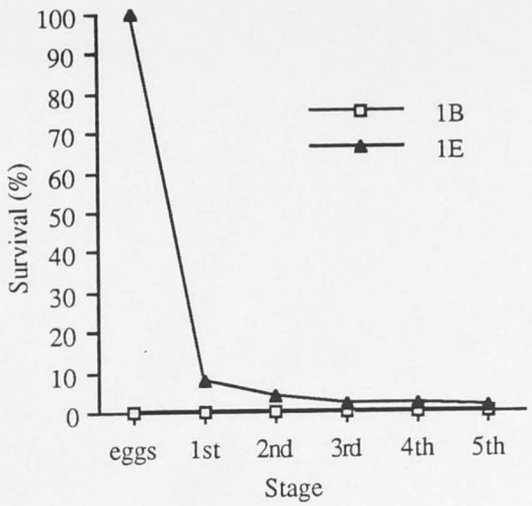

Survival (%)
100
90
80
70
60
50
40
30
20
10
0
8H
6H
eggs
1st
2nd
3rd
4th
5th
Stage

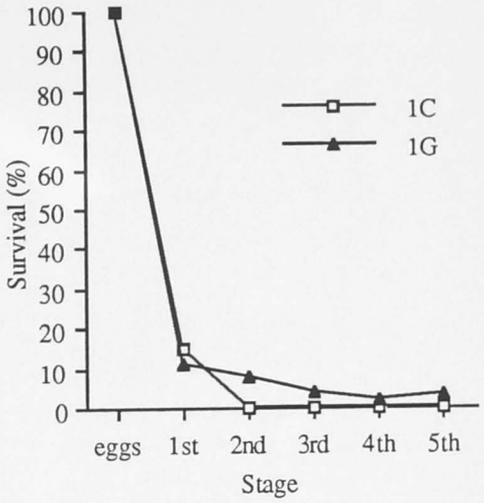
Fig. 4.20

Percentage survival of individuals of *E. punctata* in each stage (eggs to 5th instar) in the third generation (9 February to 29 June 1987) on six pairs of ant-access and ant-excluded trees.

▲ = ant-access

□ =ant-excluded


Survival (%)
100
90
80
70
60
50
40
30
20
10
0
1B
1E
eggs
1st
2nd
3rd
4th
5th
Stage


Survival (%)
100
90
80
70
60
50
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30
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1C
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eggs
1st
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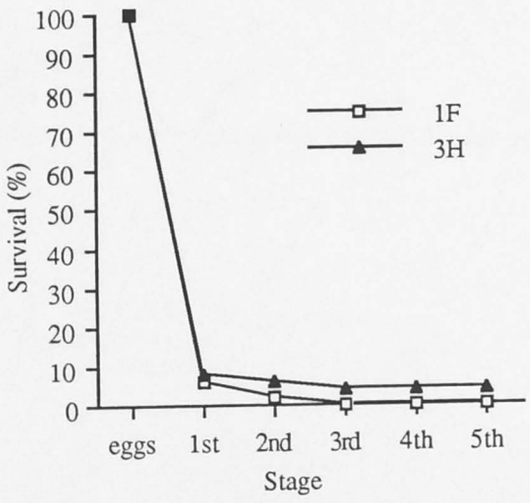
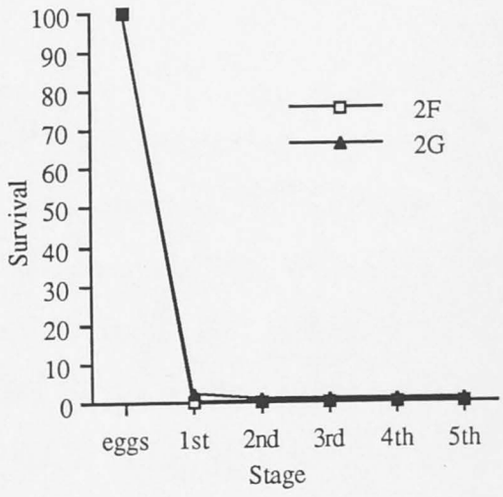
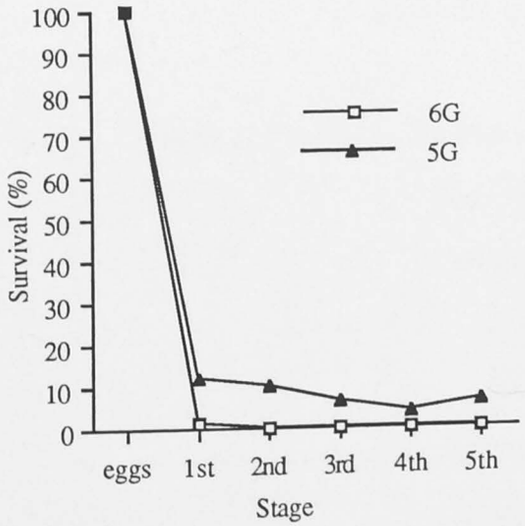
4th
5th
Stage


Survival (%)
100
90
80
70
60
50
40
30
20
10
0
1F
3H
eggs
1st
2nd
3rd
4th
5th
Stage


Survival
100
90
80
70
60
50
40
30
20
10
0
2F
2G
eggs
1st
2nd
3rd
4th
5th
Stage


Survival (%)
100
90
80
70
60
50
40
30
20
10
0
6G
5G
eggs
1st
2nd
3rd
4th
5th
Stage

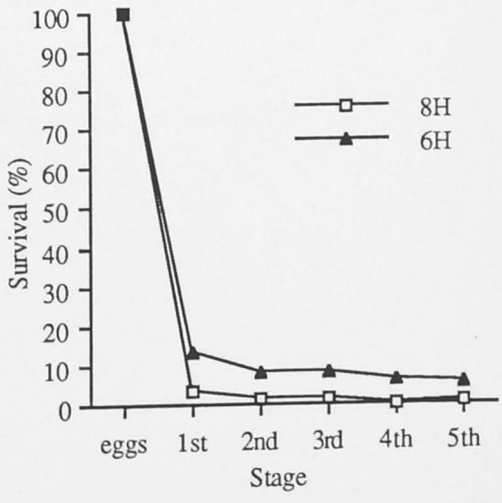

Survival (%)
100
90
80
70
60
50
40
30
20
10
0
8H
6H
eggs
1st
2nd
3rd
4th
5th
Stage

Fig. 4.21

Average age of populations of *E. punctata* on six pairs of ant-access and ant-excluded trees. Data collected from

5 Jan-13 Feb. 1987 for pair 5G-6G;

5 Jan-12 Mar. 1987 for pair 2F-2G;

5 Jan-16 Feb 1987 for pair 8H-6H;

6 Jan-2 Mar. 1987 for pair 1B-1E;

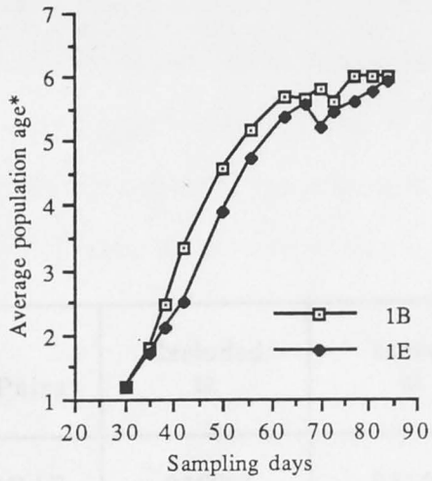
6 Jan-27 Feb 1987 for pair 1C-1G and

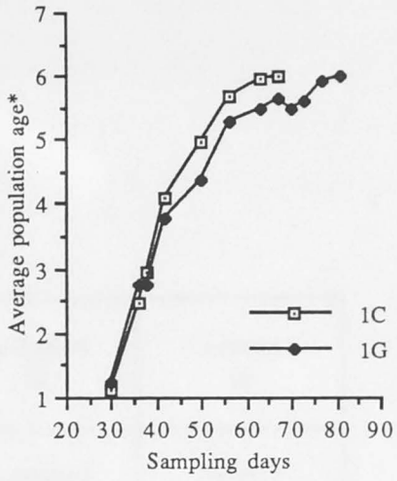
15 Dec.1986-19 Feb 1987 for pair 1F-3H were used.

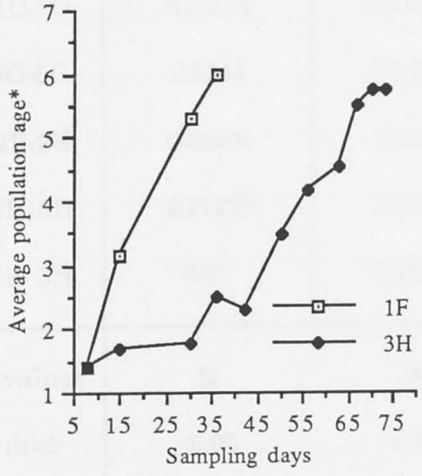
*Average population age calculated as described in Chapter 4 in section 4.2.4.

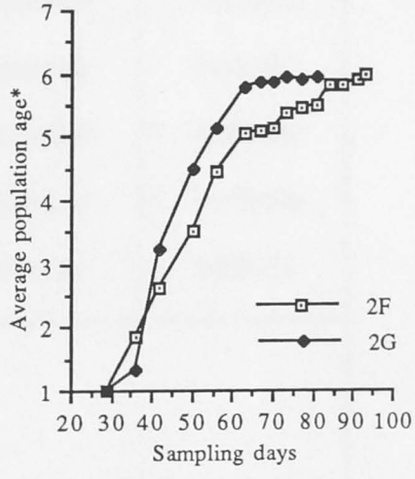
◆ = ant-access

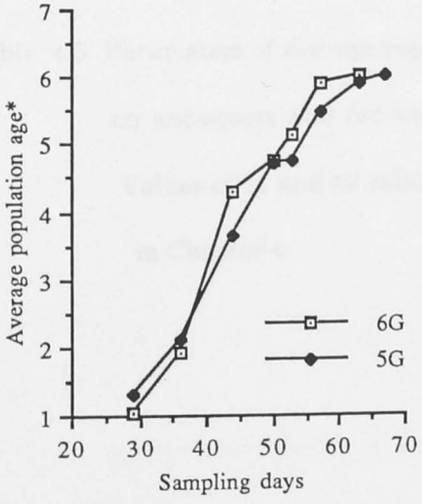
⊡ = ant-excluded

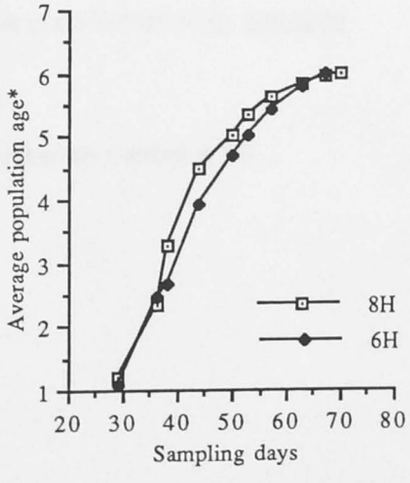

Average population age*
Sampling days
1B
1E


Average population age*
Sampling days
1C
1G


Average population age*
Sampling days
1F
3H


Average population age*
Sampling days
2F
2G


Average population age*
Sampling days
6G
5G


Average population age*
Sampling days
8H
6H

Pairs	Excluded b1	access b1	excluded b2	access b2
1B-1E	0.12063	0.11418	-0.002258	-0.0017
1C-1G	0.12114	0.10853	-0.003939	-0.002182
6G-5G	0.1344	0.12506	-0.00268	-0.001712
2F-2G	0.10405	0.1285	-0.001203	-0.002522
6H-8H	0.11479	0.12134	-0.003462	-0.002435
1F- 3H	0.21	0.07063	0.00108	0.000178
t-values	b1	b2		
df=5	-0.95	0.75		

Table 4.5 Parameters of average population age for populations of E. punctata on ant-access and ant-excluded trees.

Values of b1 and b2 calculated as described in section 4.3.3 in Chapter 4.

A similar pattern in developmental rate or average population age of individuals on both ant-access and ant-excluded trees was recorded except for pair 1F-3H. In this pair only a few nymphs were present in the first few weeks on the ant-excluded trees, whereas recruitment of young nymphs was continuous and the generations were not well defined on the ant-access tree (Appendix A5).

4.3.4 Effects of ants on ovipositing by *E. punctata*

The absence of ants had negative effects on egg laying adults. The mean number of eggs laid per female per week from 9 Feb 1987 to 1 June 1987 was estimated (as described in section 3.2.3 in Chapter 3) for all trees and there were no significant differences between ant-access and ant-excluded trees (Table 4.6). However, egg laying was recorded on 47 occasions on ant-access trees and on only 19 occasions on ant-excluded trees.

The total numbers of eggs laid on all experimental trees during the first and second field seasons are presented in Table 4.7. In both seasons many more eggs were laid on trees with ants than on trees without ants. Fifty nine percent (59%) and 81% of the total eggs were laid on the ant-access trees in the first and second field season respectively.

4.3.5 Adults on the Tangletrap bands

The numbers of adults and nymphs of *E. punctata* caught on Tangletrap bands in the first field season are presented in Table 4.8. More males were caught on each tree than females. Most of the adults were caught in weeks 2, 8, and 11, which could be an indication of movements of young adults. A number of nymphs were caught in weeks 7, 8 and 11. Only four adults were caught in the second field season.

	Mean	Range	±SD
Ant-access n=47	33.3	2-159	32.4
Ant-excluded n=19	29.7	2 - 68	21.4

Table 4.6 Number of eggs of E. punctata laid per female per week on ant-access and ant-excluded trees (data collected from 9 February 1987 to 1 June 1987).

Years	ant-access	ant-excluded
1986-87	26498	18399
1987-88	15259	3672

Table 4.7 Total number of eggs of E. punctata laid in first and second field seasons on ant-access and ant-excluded trees.

Tree nos.		1B			1C			2F			6G			8H			
DATE	WEEK	M	F	N	M	F	N	M	F	N	M	F	N	M	F	N	Total
12/12/86	1	2	-	-	3	2	-	15	4	-	4	1	-	3	-	-	34
17+22/12/86	2	4	2	-	17	6	-	36	32	-	22	17	-	7	5	-	148
29/12/86	4	1	1	-	1	1	-	11	2	-	5	1	-	-	4	-	27
22+27/1/87	7	-	1	8	-	-	-	6	1	2	-	-	3	1	-	51	73
3/2/87	8	3	5	4	2	2	3	4	4	18	11	15	21	18	16	21	147
23/2/87	11	8	5	2	-	-	-	57	50	27	10	10	1	5	1	5	181
5/3/87	13	3	2	-	-	-	-	-	-	-	7	1	1	1	1	-	16
12/3/87	14	1	3	1	-	-	1	11	6	-	-	1	-	-	1	-	25
23/3/87	15	-	1	-	-	-	-	1	4	-	-	-	-	-	-	-	6
Totals		22	20	15	23	11	4	141	103	47	59	46	26	35	28	77	

Table 4.8 Numbers of adults and nymphs of E. punctata caught on Tangletrap during the first field season.

M=Males; F=Females and N=Nymphs.

4.4 DISCUSSION

Although absence of ants decreased the survival rate in populations of *E. punctata*, the response of eurymelid populations to the removal of ants did not occur immediately after ants were removed. In the first field season, there were no significant differences between ant-access and ant-excluded populations until week 10-15 (second generation) but a marked difference occurred in the third generation. A similar finding was reported by Buckley (1983) who showed that ant attendance did not increase the population size of the membracid *Sextius virescens* (Fairmaire), or reduce mid-season mortality, but caused a significant decrease in late season mortality. Fritz (1982) also showed that ant protection had a greater impact on *Vanduzea arquata* (Membracidae) survival in the first than in the second generation.

A decrease in population numbers of eurymelids in the absence of ants may depend on the timing of ant removal and the duration of ant exclusion in relation to the population stage of the eurymelids and the time of the year. First, if ants are removed from a population (population refers to individuals on a single tree) at the time when mainly nymphs are present it is likely that predators will become more active. For example, the disappearance of early instars in pairs 1F-3H, 2F-2G and 1C-1G (Figs 4.2, 4.5 and 4.3) was probably caused by predators, such as spiders and pentatomid bugs. The removal of ants will not increase parasitism at this stage since nymphs of *E. punctata* are not commonly parasitised. However, large numbers of eggs of *E. punctata* are parasitised in the natural state and many more eggs are parasitised when ants are removed. This was clearly evident in the first season after week 9 (Fig. 4.1) and in the second season after weeks 3 to 8 (Fig. 4.8). The impact of ants on populations of *E. punctata* may partly depend on the population dynamics of the parasitoids and the degree of synchronization between parasitoid and host populations. For example, although eggs were present on the trees at the time when the first ant-exclusion experiment was started, removal of ants did not decrease the eurymelid population numbers greatly in that generation, possibly because the eggs had already

passed their susceptible stage. Alternatively, it may be that the parasitoid population that had developed from eggs of the previous generation (overwintering eggs) was not large enough to parasitise a significant number of eggs, even in the absence of ants. Second, the impact of ants on populations of *E. punctata* may depend on the developmental stage of the eggs. Eggs of *E. punctata* are attended by ants and are probably more susceptible to parasitism early in their development (Vinson 1976; Cookson and New 1980; Strand 1986; Van Alphen and Vet 1986). The absence of ants during early egg development may lead to increased parasitism.

The removal of ants also had negative effects on egg laying adults. More eggs were laid on ant-access trees in both seasons and there were more egg laying occasions on ant-access than on ant-excluded trees, although there were no significant differences in numbers of eggs laid per female per week between ant-access and ant-excluded trees. Experiments on other homopterans also showed that ant-exclusion did not have any significant effects on the fecundity of females (Gough1975; Bristow 1984). Probably more females laid eggs or the females remained longer on the ant-access trees than on the ant-excluded trees. In the first field season adults failed to lay any overwintering eggs on some ant-excluded trees (Figs 4.2, 4.4 and 4.5) and most of the eggs laid by the second generation females failed to hatch. Similar findings on the effects of ants on egg laying and successful maturation of homopterans have been reported by other authors . Bristow (1983) suggested that ant attendance acts indirectly to benefit adult *Pubilia reticulata* Van Duzee (Membracidae) as well as directly to benefit immature stages. Her study showed that in the presence of ants, females remained with the eggs until hatching and then abandoned the young nymphs sooner, in order to produce a new brood, than in the absence of ants. Females stayed with their nymphs in the absence of ants, and increased the chance of producing some survivors, but ant attendance greatly increased the number of surviving nymphs. Wood (1977) showed that ants protected nymphs of the membracid *Entylia bactriana* (German) from predators and that successful maturation of eggs and nymphs of the species was dependent upon the presence of parent females and the attendance of ants.

He also showed that the number of surviving nymphs was higher when both ants and females were present than when only the females or only the ants attended them.

The differences between the populations on ant-access and ant-excluded trees were much greater in the second field season (Fig. 4.8) than in the first field season (Fig. 4.1). This may be explained both by the age of the trees and the absence of ants. As described in Chapter 3, *E. punctata* prefers relatively young trees, and not many trees were colonised by this species in experimental blocks A and B (Fig. 3.8) in the second field season. So the removal of ants may have exacerbated an already unfavourable situation, resulting in a more rapid decrease in numbers of *E. punctata* than in the first season.

A number of adults were caught on Tangletrap bands and the possible explanations of this could be: (a) natural movement of dispersing young adults (see Chapter 3), which may be density dependent; (b) avoidance or deserting of trees that lack ants, or (c) accidental 'falling off' as a result of strong wind or rain. Similar patterns of decreasing numbers of adults on the ant-access and the ant-excluded trees during weeks 2, 8 and 11 (the highest numbers of adults were recorded on Tangletrap during these weeks) suggest either (a) or (c). More males were caught on Tangletrap than females. There are three possible explanations for this observation : (i) males may be more vagile than females, (ii) females may be more inclined to fly, or (iii) there may be more males than females in the population. It was not possible to determine the sex ratio of populations. Adults were very difficult to capture and could not be sexed on the tree because there were no obvious differences between males and females from their dorsal view.

Very few adults were caught on the Tangletrap in the second field season, possibly because the populations on the trees were smaller and the Tangletrap bands were narrower than in the first field season.

Results of the ant-exclusion experiment for populations of *E. distincta* suggest that survival of this species is also highly dependent on ant attendance. In the natural state the eggs and nymphs of *E. distincta* are probably less protected from their parasitoids and predators than those of *E. punctata* . Egg slits of *E. distincta* are not attended by ants and the egg is probably the stage most susceptible to parasitism. Even though eggs are not naturally ant-attended, fewer were laid on the ant-excluded trees than on ant-access trees (Fig. 4.15). Fewer nymphs hatched and survived on the ant-excluded trees than on the ant-access trees. Adults tended to stay and lay additional batches of eggs on the trees with ants (Fig. 4.15). More nymphs of *E. distincta* than of *E. punctata* were parasitised although the nymphs of both species are ant-attended in the natural state. Only one parasitoid (*Anteon* sp.) was reared from a fifth instar nymph of *E. punctata* whereas third, fourth and fifth instar nymphs of *E. distincta* were frequently parasitised by the same parasitoid species. This may be a consequence of the different size and colour of nymphs of these two species. The nymphs of *E. punctata* were more active and therefore were more difficult to collect than those of *E. distincta*. *E. distincta* nymphs are predominantly dark red in colour and larger in size than *E. punctata* nymphs, and may be more attractive to parasitoids. Vinson (1976) suggested that the size, colour and age play important roles in the selection of hosts by parasitoids.

The parasitoids of eggs, nymphs and adults of *E. distincta* mentioned by Evans (1931) were not encountered during this study. The species of egg and nymphal parasitoids of *E. distincta* recorded during this study were not mentioned by Evans (1931).

The observation that *E. punctata* and *E. distincta* sometimes live in the same aggregation (for example tree pairs, 1B-1C, 7A-3A) may be explained by their relationship with ants. Nymphs and adults of *E. distincta* are larger in size and probably produce more honeydew per individual than nymphs and adults of *E. punctata* . When both species are present on the same tree, individuals of the species

which is producing less total honeydew may actively seek out and aggregate with the other species to get ant attendence. A similar suggestion was made by Mc Evoy (1979) and Wood and Guttman (1982) who observed that many ant-attended membracids lived in dense aggregations which attracted more ant-protection than dispersed populations. Wood (1977) suggested that ants may encourage aggregation in order to maintain a concentrated food source for their own benefit. Eurymelids are benefited by ant attendence which protects the eurymelids from their natural enemies and reduces the growth of sooty moulds by removing honeydew. Both eurymelid species were also found in the same aggregation with scale insects, especially when the eurymelid aggregations were small. The eurymelids are probably attracted to the sedentary scale insects by the presence of ants, particularly when the eurymelids are producing less honeydew than the scale insects on the same trees.

Some ant-access trees had large populations of scale insects and the populations of *E. punctata* were not very successful on those trees, for example, pairs 1G-3E and 8B-R3D (Figs 4.10 and 4.11). This may suggest that eurymelids are not well protected from their natural enemies when they are on the same tree as large numbers of scale insects. Perhaps the large numbers of scale insects attract more ants and therefore acquire more protection than eurymelids. Alternatively, the large numbers of scale insects may attract more predators and parasitoids to the tree. Some studies suggest that the alertness and aggressiveness of ants at the food source and their protection of Homoptera is enhanced when the food source is scarce (Way 1963). Although some ant species show ownership behaviour (monopolizing a food source; aggression towards intruders; Brian 1955), most ant species do not regulate the upper limits of numbers of attended Homoptera and therefore, intensity of their ownership behaviour may vary according to their honeydew need and supply (Way 1963).

It was clear from this study that trees with ants had more scale insects on them than the trees from which ants were excluded. In the second field season scale populations continued to increase on the ant-access trees whereas only a few survived

and stayed on the ant-excluded trees throughout the season. Collins and Scott (1982) found that more individuals of the scale insect *Pulvinariella mesembryanthemi* (Vallot) (Coccidae) died due to sooty mould infestation and predators when ants were removed than when ants were present. However, some scale insects survived without ants, and this seems to be an important attribute of a species capable of colonizing new areas . But the formation of large populations of scales may be dependent upon the presence of ants (Collins and Scott 1982). Grant and Moran (1986) showed that more scale insects survived in the presence of ants than when the ants are removed. Gough (1975) found that the populations of *Eriococcus coriaceus* Maskell survived when attended by ants and ant attendance reduced the numbers of the predator, *Rhizobius ventralis* (Coccinellidae), but that all unattended populations were wiped out by *R. ventralis* .

CHAPTER - FIVE

GENERAL DISCUSSION AND CONCLUSION

5.1 SAMPLING METHODS AND DATA ANALYSIS

This is the first study on the population ecology of eurymelids but populations of other leafhoppers in grasslands have been studied. Vacuum samplers, beating and sweeping have been used to collect samples of nymphs and adults (Kiritani *et al.* 1970; Hokyo and Kuno 1977; Perfect *et al.* 1983; Buntin 1988; Cook and Perfect 1989) while eggs have been collected mainly by removing parts of the host-plants. In some studies sampling has been done by collecting individuals with their host-plants (Rothschild 1966a). The sampling method used in the present study was direct counting of the individuals on the trees. Direct counting has been used previously to compare populations of membracids with and without ants (Wood 1974; 1977; Bristow 1983; Buckley 1983). This method is non-destructive and has the advantage that the same population can be observed through time which is important because eurymelid aggregations on different individual trees in one area may be at different stages of development.

Two main difficulties were encountered in this study. These were:

(i) determining the actual duration of each stage and

(ii) counting the number of individuals of each stage in aggregations, especially on relatively large trees.

The consequences of these problems were overestimation and underestimation of the number of individuals in different stages, and inaccuracy in counts. Sometimes

it was necessary to disturb nymphs in dense aggregations in order to count the individuals in different stages and counting inaccuracy could occur since nymphs tended to move away from the disturbance.

The methods could be improved by:

(i) sampling populations daily, or at least every second day during the developmental period, in order to determine the actual duration of each stage,

(ii) selecting relatively small trees where populations could be counted more accurately, and

(iii) checking counting accuracy by counting live individuals in different stages on a number of host plants and then recounting the same individuals after collecting and killing them. If there was a discrepancy between the two counts, the data derived from direct counting on the host plants could be adjusted accordingly.

5.2 LIFE HISTORY STRATEGIES OF *E. PUNCTATA* AND *E. DISTINCTA*

Eurymela distincta and *Eurymeloides punctata* have quite different life history strategies although they often occur on the same trees and even in the same aggregations at Millpost. *E. distincta* has one generation per year and adults overwinter under the bark of mature trees. *E. punctata* has three generations per year and eggs overwinter and hatch in the following spring. However, the life history traits of *E. punctata* can vary under different climatic conditions. For example this study showed that (i) overwintering eggs contained well-developed embryos which could hatch and undergo further development in winter under warmer conditions, indicating that winter eggs are in a state of quiescence; (ii) some adults survived winter under wood chips on the ground where the temperature presumably was higher than on the tree; (iii) egg-laying continued until much later in 1988 when the winter was less severe than in 1987 and (iv) some adults survived and egg-laying continued in winter

in Canberra where the climate is less severe than at Millpost. These results indicate that *E. punctata* shows a high degree of responsiveness to changes in environmental conditions. Similar findings for the overwintering habits of aphids are discussed by Tauber *et al.* (1986). The observations summarised above suggests that *E. punctata* may have more than three generations, or possibly breed continuously in a warmer climate. Considerable variability in seasonal occurrence between years according to changes in climate and latitude has also been recorded in other insects (De Long 1971; Denno *et al.* 1981; Tauber *et al.* 1986).

The eggs of *E. punctata* are attended by ants whereas those of *E. distincta* are not, although nymphs and adults of both species are ant-attended. Further work needs to be done on the secretion that covers the egg slits of both species to determine its composition and its efficiency in protecting eggs from natural enemies and adverse weather.

Counts of populations of *E. distincta* showed that a single tree could have as many as 90 egg slits. Only one or two individuals of *E. distincta* were found on each tree, indicating that each female lays many eggs (Appendix B14 - B19). Further investigation of *E. distincta* to determine the fecundity of females and the percentage of eggs parasitised would allow more detailed comparison with the biology of *E. punctata.*

5.3 HOST-PLANT SELECTION AND ESTABLISHMENT OF POPULATIONS OF *E. PUNCTATA*

The study showed that young eucalypts were greatly preferred by eurymelids. Although the factors that infuence eurymelids in selecting their host plants are not known it is possible that younger trees have higher levels of nutrients. Other studies have shown that the fitness (fecundity, growth rate, survival and adult size) of

homopterans is positively related to host-plant quality (Fennah 1953; Mittler 1958; Van Emden 1966; Dixon 1969; Auclair 1976; Horsfield 1977; McClure 1977, 1979; Mitsuhashi and Koyama 1977; Visscher Neumann 1982; Raven 1983; Washburn *et al.* 1985). The present study also demonstrated that ant-attendance plays an important role in the persistence of eurymelid populations. Similar findings were reported in previous work on ant-attended homopterans (Flanders 1951; Nixon 1951; Way 1963; Wood 1974; 1977; Gough 1975; Collins and Scott 1982; Fritz 1982; Bristow 1983; Buckley 1983; Beattie 1985; Grant and Moran 1986; Maschwitz *et al.* 1987). My study suggests that the establishment and maintenance of eurymelid populations depends on both host-plant age and the presence of ants.

Eurymelids are not major pests of eucalypts, probably because of the action of their natural enemies, however, the effects of eurymelids on young eucalypts are not known. Studies on ant-homopteran associations and negative effects of homopterans on plant growth have been recorded by different authors (Gough 1975; Newbery 1980; Briese 1982; Buckley 1983; Mills 1984; Whittaker 1984). It appears that eurymelids could be eradicated by excluding the attendant ants.

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APPENDIX A

Block and trees used in the first field season (Dec. 1986-July 1987)

1SATrial (Block A) *(E. viminalis)*

Pairs of trees	Tree numbers and treatment	
	Ant-access (control)	ant-excluded
1E-1B	1E	1B
1G-1C	1G	1C
3H-1F	3H	1F
2G-2F	2G	2F
5G-6G	5G	6G
6H-8H	6H	8H

1SATrial refers to block A

APPENDIX A2

Species- *Eurymeloides punctata*
Plot no.- 1SA trial
Tree no.- 1E
Treatment- ant-access
Year - 1 (15 Dec. 1986-6 July 1987)

weeks	no. of obs.	egg rings	egg slits	1st	2nd	3rd	4th	5th	adults	other observations
1	1	5	50	0	0	0	0	0	6.5	
2	1	4	40	0	0	0	0	0	6	
4	1	8	80	120	27	0	0	0	5	hatching
5	1	0	0	320	200	100	20	0	5	
6	2	0	0	69.5	102	68.5	27.5	11	4	
7	1	0	0	12	25	55	120	98	4	coccinellid larvae+ adults
8	1	0	3	0	8	32	45	140	60	
9	1	0	3	0	0	8	6	50	75	
10	2	0	0	0	1.5	10.5	10	68	85	
11	2	7	75	0	0	3.5	1.5	9	48.5	
12	2	4	50	0.5	0	1	0.5	3.5	19	
13	2	3	26	0	0	0	0.5	3	11.5	
14	2	0	0	20	0	0	0	1.5	19.5	hatching from eggs noted on wk-8
15	1	0	0	64	6	0	0	0	17	
16	1	0	0	7	25	1	0	0	10	
17	1	0	0	7	12	10	1	0	15	
18	1	3	19	6	7	12	8	0	20	egg laying
19	1	5	33	0	7	9	13	0	22	
20	1	4	21	0	0	4	7	4	26	egg laying
21	1	5	71	0	0	0	2	12	15	
22	1	2	22	0	0	0	2	8	16	
23	1	9	68	0	0	0	1	9	23	egg laying
24	1	1	17	0	0	0	0	0	5	
25	1	2	39	0	0	0	0	0	0	
26	1	0	0	0	0	0	0	0	2	some ants on the tree
27	1	0	0	0	0	0	0	0	0	
28	1	0	0	0	0	0	0	0	0	
29	1	0	0	0	0	0	0	0	0	
30	1	0	0	0	0	0	0	0	0	

Species- *Eurymeloides punctata*
Plot no.- 1SA trial
Tree no.- 1G
Treatment- ant-access
Year - 1 (15 Dec. 1986-6 July 1987)

weeks	no. of obs.	egg rings	egg slits	1st	2nd	3rd	4th	5th	adults	
1	1	13	130	23.5	0	0	0	0	10	
2	1	13	120	4	19	0	0	0	4	
4	1	2	20	421	154	0	0	18	0	
5	1	0	0	50	180	190	130	0	12	hatching
6	2	0	0	0	70.5	109.5	85	19	4.5	
7	1	0	0	0	0	45	35	98	9	
8	1	0	0	0	0	0	20	50	60	
9	1	0	0	0	0	2	8	33	60	
10	2	1	5	0	0	0	5	20	47.5	
11	2	2	27	0	0	0	3.5	2	29.5	
12	2	6	50	0	0	0	0	0	10.5	laying
13	2	0	6	0	0	0	0	0.5	5.5	
14	2	0	0	2.5	5	0	0	0.5	9	
15	1	1	8	30	8	0	0	0	9	hatching from eggs noted on wk-12
16	1	0	0	28	25	5	2	0	5	
17	1	0	0	17	24	15	5	0	7	
18	1	0	0	6	5	14	10	1	7	
19	1	0	0	0	0	2	7	7	7	
20	1	0	0	0	0	3	5	7	9	
21	1	0	0	0	0	1	0	12	7	
22	1	6	51	0	0	1	0	7	14	
23	1	0	0	0	0	0	1	7	17	laying;some ads at base of trunk
24	1	1	11	0	0	0	1	2	3	
25	1	2	30	0	0	0	0	0	2	
26	1	0	0	0	0	0	0	0	4	
27	1	0	0	0	0	0	0	0	0	
28	1	0	0	0	0	0	0	0	0	
29	1	0	0	0	0	0	0	0	0	
30	1	0	0	0	0	0	0	0	0	

APPENDIX A4

Species- *Eurymeloides punctata*
Plot no.- 1SA trial
Tree no.- 2G
Treatment- ant-access
Year - 1 (15 Dec. 1986-6 July 1987)

weeks	no. of obs.	egg rings	egg slits	1st	2nd	3rd	4th	5th	adults	other observations
1	1	6	60	0	0	0	0	8	65	
2	1	1	10	0	0	0	0	0	27	
4	1	20	200	60	0	0	3	1	2	hatching
5	1	0	0	180	90	0	0	0	5	
6	1	0	0	0	40	100	70	10	4	
7	1	0	0	0	0	0	60	30	10	
8	1	0	0	0	0	4	20	50	45	
9	1	2	18	15	0	5	3	10	120	
10	2	10	100	8.5	2.5	5	2.5	10	100	
11	2	10	134	3.5	4.5	1.5	0	2	50	
12	2	14	43	2.5	1.5	2	1.5	3	19	cockroaches
13	2	35	5	5.5	0	0.5	0.5	1	21.5	wasps on eggs rings;";hatching from wk-8
14	2	0	0	8.5	0	0	0	1.5	16.5	
15	1	0	0	10	0	0	0	2	20	
16	1	0	0	12	1	1	0	0	15	
17	1	0	0	10	4	4	0	0	10	hatching from the eggs noted on wk-11
18	1	0	0	2	5	0	1	0	10	
19	1	0	0	2	6	4	4	0	10	
20	1	0	0	2	3	5	6	4	12	
21	1	0	0	0	1	7	6	2	10	
22	1	0	0	0	1	5	6	5	14	laying
23	1	0	0	0	0	3	9	5	15	
24	1	0	0	0	0	2	4	2	4	
25	1	0	0	0	0	0	3	3	2	laying
26	1	0	0	0	0	0	3	2	2	
27	1	0	0	0	0	0	1	1	0	
28	1	0	0	0	0	0	0	0	0	
29	1	0	0	0	0	0	0	0	0	
30	1	0	0	0	0	0	0	0	0	

Species- *Eurymeloides punctata*

Plot no.- 1SA trial

Tree no.- 3H

Treatment- ant-access

Year - 1 (15 Dec. 1986-6 July 1987)

weeks	no. of obs.	egg rings	egg slits	1st	2nd	3rd	4th	5th	adults	other observations
1	1	6	60	40	25	6	8	0	1	
2	1	0	0	8	25	8	5	5	1	
4	1	0	0	40	45	10	20	25	3	hatching
5	1	0	0	10	12	50	20	25	6	
6	1	0	0	0	4	20	31	20	11	
7	1	0	0	0	0	10	22	60	0	coccinellids; spiders
8	1	0	0	0	0	0	3	14	23	"
9	1	0	0	0	0	0	0	8	22	
10	2	2	11	0	0	0	0	3	7.5	
11	2	2	36	0	0	0	0	0	14.5	
12	2	3	43	0	0	0	0	0	11.5	
13	2	3	13	0	0	0	0	0	8	
14	2	0	0	15	0	0	0	0	9	
15	1	0	0	25	10	4	0	0	0	
16	1	0	0	19	24	7	3	1	4	
17	1	0	0	14	18	17	12	1	3	
18	1	0	0	0	9	12	17	3	2	
19	1	0	0	0	5	9	13	16	4	
20	1	1	6	0	0	4	7	22	10	egg laying
21	1	1	10	0	0	0	4	8	10	
22	1	0	0	0	0	0	2	10	10	
23	1	4	30	0	0	0	0	6	5	
24	1	0	0	0	0	0	0	1	1	
25	1	0	0	0	0	0	0	1	0	
26	1	0	0	0	0	0	0	0	0	
27	1	0	0	0	0	0	0	0	0	
28	1	0	0	0	0	0	0	0	0	
29	1	0	0	0	0	0	0	0	0	
30	1	0	0	0	0	0	0	0	0	

Species- *Eurymeloides punctata*										
Plot no.- 1SA trial										
Tree no.-5G										
Treatment- ant-access										
Year - 1 (15 Dec. 1986-6 July 1987)										
weeks	no. of obs.	egg rings	egg slits	1st	2nd	3rd	4th	5th	adults	other observations
1	1	15	150	40	35	30	20	60	30	
2	1	15	140	0	0	5	15	16	6	
4	1	2	10	190	40	20	5	5	4	eggs hatching
5	1	0	0	32	75	25	10	4	2	
6	1	0	0	0	0	50	20	17	0	
7	1	0	0	0	0	0	25	50	2	
8	2	0	0	0	0	0	11.5	33	17	spiders
9	1	2	15	0	0	0	0	5	35	
10	2	4	38	0	0	0	0	0	18.5	
11	2	6	108	12	0	0	0	0	10.5	hacthing from eggs noted in wk-8
12	2	7	15	12	6	0	0	0	10	
13	2	0	20	20.5	13	6.5	0	0	4.5	
14	2	1	8	24	23	13	6.5	0	5	hatching from eggs noted in wk-11
15	1	0	0	96	25	13	17	10	2	
16	1	0	0	23	54	24	9	16	0	
17	1	0	0	17	43	21	10	20	0	
18	1	0	0	7	18	32	11	16	17	
19	1	0	0	0	8	30	20	25	20	
20	1	0	2	0	7	5	19	22	13	egg laying
21	1	0	6	0	0	3	12	37	12	
22	1	0	0	0	0	4	7	40	18	
23	1	0	0	0	0	1	0	20	11	
24	1	0	0	0	0	0	0	6	7	
25	1	0	6	0	0	0	0	0	2	
26	1	0	0	0	0	0	0	0	0	
27	1	0	0	0	0	0	0	0	1	
28	1	0	0	0	0	0	0	0	0	
29	1	0	0	0	0	0	0	0	0	
30	1	0	0	0	0	0	0	0	0	

Species- *Eurymeloides punctata*
Plot no.- 1SA trial
Tree no.- 6H
Treatment- ant-access
Year - 1 (15 Dec. 1986-6 July 1987)

weeks	no. of obs.	egg rings	egg slits	1st	2nd	3rd	4th	5th	adults	other observations
1	1	23	200	0	0	0	0	0	15	
2	1	8	100	0	0	0	0	0	11	
4	1	22	210	460	38	5	0	0	1	egg laying; hatching
5	1	0	0	80	150	100	80	0	3	
6	2	0	5	17.5	84	78	72.5	39	2	
7	1	3	22	0	0	0	40	55	7	coccinellid ads + spiders
8	2	0	0	0	0.5	0	10	55.5	25.5	egg laying; spiders
9	1	3	12	0	0	0	0	10	35	
10	2	6	34	3.5	4	1	0	0	28	
11	2	5	27	3.5	7	1	0	0	12	
12	2	1	24	1.5	2.5	4	3.5	1	7	hatching from eggs noted in wk-8
13	2	0	0	8	0	3	2.5	1	5	
14	2	0	0	60	7.5	0.5	3	2	7.5	
15	1	0	0	50	27	7	1	3	4	
16	1	0	0	7	16	21	8	1	4	
17	1	0	0	19	5	21	11	5	3	
18	1	0	0	4	7	7	7	4	3	
19	1	0	0	2	5	7	8	14	3	
20	1	0	0	0	6	9	7	13	5	
21	1	0	0	0	1	6	5	18	10	spiders
22	1	0	0	0	0	5	4	8	10	
23	1	0	0	0	0	0	2	4	10	
24	1	0	0	0	0	0	1	2	2	
25	1	0	0	0	0	0	0	0	0	
26	1	0	0	0	0	0	1	3	4	
27	1	0	0	0	0	0	1	1	1	
28	1	0	0	0	0	0	0	1	3	
29	1	0	0	0	0	0	0	1	2	
30	1	0	0	0	0	0	0	0	0	2 nymphs found dead(4th+5th)

APPENDIX A8

Species - *Eurymeloides punctata*										
Plot no.- 1SA trial										
Tree no.- 1B										
Treatment- ant-excluded										
Year - 1 (15 Dec. 1986-6 July 1987)										
weeks	no. of obs.	egg rings	egg slits	1st	2nd	3rd	4th	5th	adults	other observations
1	1	6	60	0	0	0	0	0	11	
2	1	7	60	0	0	0	0	0	3	
4	1	3	30	270	64	0	0	0	0	hatching
5	1	0	0	115	105	58	5	1	3	"; spiders
6	2	0	0	6.5	49	45	18.5	5.5	6.5	
7	1	0	0	0	0	12	20	45	8	spiders
8	1	0	0	0	0	2	13	30	30	"
9	1	0	0	0	0	0	3	10	35	"
10	2	0	0	0	0	1.5	3.5	7	37.5	
11	2	0	0	0	0	0	2.5	3	22.5	
12	2	0	0	0	0	0	0	0	9	
13	2	0	0	0	0	0	0	0	3.5	
14	2	0	0	0	0	0	0	0	0	
15	1	0	0	0	0	0	0	0	0	
16	1	0	0	0	0	0	0	0	0	
17	1	0	0	0	0	0	0	0	2	
18	1	0	0	0	0	0	0	0	2	
19	1	0	0	0	0	0	0	0	0	
20	1	0	0	0	0	0	0	0	1	
21	1	0	0	0	0	0	0	0	0	
22	1	0	0	0	0	0	0	0	1	
23	1	0	0	0	0	0	0	0	0	
24	1	0	0	0	0	0	0	0	0	
25	1	0	0	0	0	0	0	0	0	
26	1	0	0	0	0	0	0	0	0	
27	1	0	0	0	0	0	0	0	0	
28	1	0	0	0	0	0	0	0	0	
29	1	0	0	0	0	0	0	0	0	
30	1	0	0	0	0	0	0	0	0	

Species- *Eurymeloides punctata*
Plot no.- 1SA trial
Tree no.- 1C
Treatment- ant-excluded
Year - 1 (15 Dec. 1986-6 July 1987)

weeks	no. of obs.	egg rings	egg slits	1st	2nd	3rd	4th	5th	adults	other observations
1	1	11	100	0	0	0	0	1.5	29.5	
2	1	0	0	0	0	0	0	0	5	
4	1	9	90	400	50	4	0	0	0	hatching; coccinellid adults
5	1	0	0	3	65	41	10	1	0	coccinellid with nymphs; spiders
6	2	0	0	0.5	14	32.5	32.5	8	2	
7	1	0	0	4	4	0	5	45	4	
8	1	0	0	0	1	0	0	15	33	coccinellid adults
9	1	0	0	0	0	0	0	1	23	"
10	2	1	8	6	0	0	0	0	16	"
11	2	0	0	0.5	0	0	0	0	7.5	'
12	2	1	2	0	0	0	0	0	8	
13	2	0	0	0	0	0	0	0	2.5	
14	2	0	0	0	0	0	0	0	0.5	
15	1	0	0	6	0	0	0	0	0	
16	1	0	0	0	0	0	0	0	2	
17	1	0	0	0	0	0	0	0	1	
18	1	0	0	0	0	0	0	0	3	
19	1	0	0	0	0	0	0	0	2	
20	1	0	0	0	0	0	0	0	1	
21	1	0	0	0	0	0	0	0	0	
22	1	0	0	0	0	0	0	0	0	
23	1	2	12	0	0	0	0	0	1	
24	1	0	0	0	0	0	0	0	0	
25	1	0	0	0	0	0	0	0	0	
26	1	0	0	0	0	0	0	0	0	
27	1	0	0	0	0	0	0	0	0	
28	1	0	0	0	0	0	0	0	0	
29	1	0	0	0	0	0	0	0	0	
30	1	0	0	0	0	0	0	0	0	

Species- *Eurymeloides punctata*
Plot no.- 1SA trial
Tree no.- 2F
Treatment- ant-excluded
Year - 1 (15 Dec. 1986-6 July 1987)

weeks	no. of obs.	egg rings	egg slits	1st	2nd	3rd	4th	5th	adults	other observations
1	1	5	50	0	0	0	0	8	43	
2	1	11	100	0	0	0	0	0	9	
4	1	19	150	110	0	0	0	0	4	egg laying
5	1	0	0	60	160	25	0	0	5	hatching; coccinellid ads. with 2nd ins;
6	1	2	10	40	60	50	40	12	3	
7	1	2	3	25	30	40	30	70	5	robber flies
8	1	0	0	0	10	45	50	80	45	
9	1	0	0	6	0	15	15	50	50	
10	2	0	0	2.5	0	18	10	32.5	59	
11	2	10	38	0	1.5	4	8	19	47.5	
12	2	2	42	0	0	1.5	2.5	8.5	27.5	
13	2	1	3	0	0	0	1.5	4.5	29	
14	2	0	0	0	0	0	0.5	0	15	coccinellid adults
15	1	0	0	1	0	0	1	0	14	
16	1	0	0	1	0	0	1	0	14	
17	1	0	0	0	0	0	0	0	12	
18	1	0	0	0	0	0	0	0	10	
19	1	0	0	0	0	0	0	0	6	1 E.distincta on the tree
20	1	0	0	0	0	0	0	0	4	"
21	1	0	0	0	0	0	0	0	1	"
22	1	0	0	0	0	0	0	0	1	"
23	1	0	0	0	0	0	0	0	1	ED adult is very sticky, failed to fly
24	1	0	0	0	0	0	0	0	1	
25	1	0	0	0	0	0	0	0	0	
26	1	0	0	0	0	0	0	0	0	
27	1	0	0	0	0	0	0	0	0	
28	1	0	0	0	0	0	0	0	0	
29	1	0	0	0	0	0	0	0	0	
30	1	0	0	0	0	0	0	0	0	

Species- *Eurymeloides punctata*
Plot no.- 1SA trial
Tree no.- 1F
Treatment- ant-excluded
Year - 1 (15 Dec. 1986-6 July 1987)

weeks	no. of obs.	egg rings	egg slits	1st	2nd	3rd	4th	5th	adults	other observations
										coccinellids
1	1	8	70	35	15	3	0	0	0	feeding on 1st ins.
2	1	2	20	0	4	6	6		1	
4	1	0	0	10	0	0	0	2	1	
5	1	0	0	0	0	3	0	0	1	
6	1	0	0	0	0	0	0	0	0	
7	1	0	0	0	0	0	0	0	0	
8	1	0	0	0	0	0	0	0	0	
9	1	0	0	0	0	0	0	0	14	
10	2	0	0	0	0	0	0	0	6	
11	2	0	0	0	0	0	0	0	4	
12	2	1	11	0	0	0	0	0	4	
13	2	0	4	0	0	0	0	0	2	
14	2	0	0	0	0	0	0	0	1.5	
15	1	0	0	0	0	0	0	0	0	
16	1	0	0	0	0	0	0	0	0	
17	1	0	0	8	2	0	0	0	0	
18	1	0	0	0	0	0	0	0	2	
19	1	0	0	0	0	0	0	0	0	
20	1	0	0	0	0	0	0	0	0	
21	1	0	0	0	0	0	0	0	1	
22	1	0	0	0	0	0	0	0	2	
23	1	0	0	0	0	0	0	0	0	
24	1	0	0	0	0	0	0	0	0	
25	1	0	0	0	0	0	0	0	0	
26	1	0	0	0	0	0	0	0	0	
27	1	0	0	0	0	0	0	0	0	
28	1	0	0	0	0	0	0	0	0	
29	1	0	0	0	0	0	0	0	0	
30	1	0	0	0	0	0	0	0	0	

Species- *Eurymeloides punctata*										
Plot no.- 1SA trial										
Tree no.-6G										
Treatment- ant-excluded										
Year - 1 (15 Dec. 1986-6 July 1987)										
weeks	no. of obs.	egg rings	egg slits	1st	2nd	3rd	4th	5th	adults	other observations
1	1	18	160	0	0	0	0	0	50	
2	1	14	310	0	0	0	0	0	11	
4	1	32	320	525	30	0	0	0	0	
5	1	0	0	50	50	40	0	0	0	coccinellid adults
6	1	0	0	0	0	23	115	87	2	
7	1	0	0	0	0	0	80	160	15	coccinellid ad+lar.; robber flies
8	2	0	0	0	0	0	2.5	111	94	egg laying;coccinellid; spiders
9	1	2	14	0	0	0	0	0	45	"
10	2	12	110	0	0	0	0	0	36	"
11	2	4	123	0	0	0	0	0	26.5	egg laying; cockroaches
12	2	8	133	0	0	0	0	0	13.5	egg laying; ants on the tree
13	2	5	24	0	0	0	0	0	8	
14	2	0	0	6	0	0	0	0	8.5	
15	1	0	0	25	0	0	0	0	7	
16	1	0	0	0	0	0	0	0	13	
17	1	0	0	3	0	0	0	0	9	
18	1	0	0	1	9	4	1	0	8	
19	1	0	0	0	2	5	3	0	7	
20	1	0	0	0	0	8	2	1	4	egg laying
21	1	0	0	0	0	0	6	3	2	
22	1	2	10	0	0	0	2	5	5	
23	1	2	10	0	0	0	3	6	2	
24	1	0	0	0	0	0	0	2	2	
25	1	0	0	0	0	0	0	0	0	
26	1	2	12	0	0	0	0	0	0	
27	1	0	0	0	0	0	0	0	0	
28	1	0	0	0	0	0	0	0	0	
29	1	0	0	0	0	0	0	0	0	
30	1	0	0	0	0	0	0	0	0	

Species- *Eurymeloides punctata*
Plot no.- 1SA trial
Tree no.- 8H
Treatment- ant-excluded
Year - 1 (15 Dec. 1986-6 July 1987)

weeks	no. of obs.	egg rings	egg slits	1st	2nd	3rd	4th	5th	adults	other observations
1	1	20	180	0	0	0	0	0	12	
2	1	21	220	0	0	0	0	0	5	
4	1	6	60	500	112	5	0	0	1	hatching
5	1	0	0	20	100	50	15	0	0	
6	2	0	0	4	31	117.5	105	86.5	0	ants on the tree (removed)
7	1	0	0	0	0	0	60	150	60	
8	2	0	0	0	0	0	12.5	83.5	122.5	coccinellid ad + larvae
9	1	0	0	0	0	0	0	14	70	"
10	2	1	17	0	0	0	0	1.5	45	
11	2	3	7	0	0	0	0	0	21.5	
12	2	5	32	0	0	0	0	0	11	
13	2	7	28	1	0	0	0	0	8.5	
14	2	0	0	1	1	0	0	0	10.5	ants on the tree (removed)
15	1	0	0	4	0	2	0	0	6	coccinellid adults
16	1	0	0	8	2	2	0	0	7	
17	1	0	0	2	1	1	1	0	4	coccinellid ads; cockroaches
18	1	0	0	3	2	2	0	2	8	ants on the tree (removed)
19	1	2	16	0	1	1	1	1	6	
20	1	0	0	0	1	0	2	0	2	
21	1	0	0	0	0	0	0	2	1	
22	1	0	0	0	0	0	0	2	1	
23	1	0	0	0	0	0	0	1	1	
24	1	0	0	0	0	0	0	0	0	
25	1	0	0	0	0	0	0	0	0	
26	1	0	0	0	0	0	0	0	0	
27	1	0	0	0	0	0	0	0	0	
28	1	0	0	0	0	0	0	0	0	
29	1	0	0	0	0	0	0	0	0	
30	1	0	0	0	0	0	0	0	0	

Species- Eurymela distincta					
block-A					
tree no.- 2G					
year- 1 (5 Jan. 1987 - 18 May 1987)					
Date	egg rings	egg slits	toal nos. of nymphs (instars)	adults	parasitised nymphs*
5/1/87	7	120	33 (1st + 2nd)		
19/1			153 (1st-5th)		
27/1			180 (1st-5th)		
30/1			200 (1st-5th)		
9/2/			80 (2nd-5th)	50	
13/2			56 (2nd-5th)	70	20
16/2			45 (2nd-5th)	46	
19/2			45 (2nd-5th)	53	15
23/2			40 (3rd-5th)	60	15
27/2			30 (3rd-5th)	66	20
5/3			18 (3rd-5th)	60	18
9/3			12 "	68	12
11/3			8 (3rd-4th)	60	8
18/3			3 (3rd-5th)	50	3
23/3				58	
1/4			1 (5th)	50	
6/4				50	
13/4				50	
21/4				50	
27/4				33	
6/5				0	
11/5				0	
18/5				1	
* only 3rd, 4th and 5th instar nymphs were parasitised.					

Months	Egg slits	Hatching	Nymphs	Adults
June (mid)	Many	- wood chips)	- and under	Few (on the tree
Late June	"	-	-	Few (under wood chips)
Early July	"	-	-	"
Mid July	"	-	-	"
Late July	some egg slits open with dead pronymphs	Few	Few dead 1st instars	"
Early Aug.	"	"	-	"
Mid Aug.	"	Failure in hatching	-	"
Late Aug	"	Few hatching	Few 1st instars	" (1 *E.distincta* ad)
Early Sept	Few new egg slits	"	Some 1st instars	Few adults on the tree
Mid Sept.	Some new egg slits	Some hatching	Many 1st instars	" (mating E.distincta)
Late Sept	"	"	Many early instar nymphs	"
Early Oct.	"	"	"	"
Mid Oct	"	"	"	"
Late Oct	"	"	All instars	" (E.distincta: mating; egg laying)

Table The abundance of *Eurymeloides punctata* and *Eurymela distincta* at Millpost from June 1987 to October 1987.

APPENDIX B

Blocks and trees used in the second field season (Nov. 1987-June 1988)

Pairs of trees	Tree numbers and treatmen		Eurymelid species occurred and studied on paired trees.	
	ant-access (control)	ant-excluded	*E. punctata*	*E. distincta*
Block A (1SA Trial)			*	*
1B-1C	1B	1C	*	*
3E-1G	3E	1G	*	-
R3D-8B	R3D	8B	*	-
8G-2B	8G	2B	*	*
7A-3A	7A	3A	*	-
Block B (1SA New)				
1G-3A	1G	3A		

* = both species were present on the trees and studied.

- = one species was present and studied.

1SA Trial refers to block A and 1SA New refers to block B.

Species: *Eurymeloides punctata*

Plot no: 1SA Trial

Tree no: 1B

Treatment- ant-access

Year-2 (9 Nov 1987-18 Apr 1988)

week	no. of obs.	egg rings	egg slits	1st	2nd	3rd	4th	5th	adults	other observations
1	1	0	0	20	0	0	0	4	3	
2	1	4	35	2	31	0	0	4	1	
3	1	0	0	2	8	6	10	0	1	
4	1	0	0	15	2	6	21	0	2	
5	1	0	0	2	8	6	6	19	8	
6	1	8	85	0	2	3	2	13	13	1 ad laying eggs
7	1	5	38	0	0	1	4	2	12	
8	1	15	120	13	2	0	0	1	0	
9	2	0	0	29	21.5	9	0.5	0	2	
10	2	7	27	12	10	12.5	9.5	4	0.5	dryinid wasp holding a vth ins.
11	2	0	11	31.5	18.5	28.5	23	26	2.5	
12	2	0	0	9.5	12	16	38.5	37.5	18	1parasitised nymph (vth ins.)
13	2	2	30	0.5	8.5	11.5	17	20	13.5	some scale insects
14	1	1	7	0	0	11	12	17	8	1 ad laying eggs
15	1	4	41	5	0	1	14	11	9	
16	2	5	49	9.5	1	0	3	14.5	4.5	
17	1	0	0	6	3	2	3	2	0	
18	1	0	0	0	2	3	0	0	0	
19	1	0	0	0	0	1	3	0	0	
20	1	0	0	0	0	0	2	0	0	
21	1	0	0	0	0	0	0	0	0	increased no. of scale insects
22	1	0	0	0	0	0	0	0	0	
23	1	0	0	0	0	0	0	0	0	

Species *Eurymeloides punctata*
Plot no.- 1SA Trial
Tree no.- 3E
Treatment- ant-access
Year 2 (9 Nov 1987- 30 May 1988)

week	no. of obs.	egg rings	egg slits	1st	2nd	3rd	4th	5th	adults	other observations
1	1	0	0	60	5	5	0	6	1	
2	1	0	0	10	20	5	3	6	0	
3	1	0	0	0	0	2	5	4	3	
4	1	0	0	0	0	1	3	4	1	
5	1	1	7	0	0	0	4	12	4	
6	1	1	9	0	0	0	0	4	3	scale insects
7	1	1	7	0	0	0	0	0	1	coccinellid larvae, spiders
8	1	0	0	0	0	0	0	0	0	"
9	2	0	0	0	0	0	0	0	0	coccinellid larvae and adults
10	2	0	0	0	0	0	0	0	0	tree is covered with scale insects
11	2	0	0	0	0	0	0	0	1	
12	2	0	0	0	0	0	0	0	0	
13	2	0	0	0	0	0	0	0	0	
14	1	0	0	0	0	0	0	0	0	
15	1	0	0	0	0	0	0	0	0	
16	2	0	0	0	0	0	0	0	0	
17	1	0	0	1	0	0	0	0	0	
18	1	0	0	0	0	0	0	0	0	
19	1	0	0	0	0	0	0	0	0	
20	1	1	8	0	0	0	5	0	1	
21	1	0	0	2	0	0	0	4	1	
22	1	0	0	0	5	0	0	4	1	
23	1	0	0	0	4	0	0	3	1	
24	1	0	0	0	3	5	0	1	0	
25	1	0	0	0	1	5	1	0	1	
26	1	0	0	0	0	0	4	0	0	
28	1	0	0	0	0	0	0	1	0	
29	1	0	0	0	0	0	0	1	0	

Species- *Eurymeloides punctata*
Plot no.-1SA Trial
Tree no.-R3D
Treatment- ant-access
Year-2 (9 Nov1987-18 Apr 1988)

week	no. of obs.	egg rings	egg slits	1st	2nd	3rd	4th	5th	adults	other observations
1	1	0	0	25	4	0	0	3	0	
2	1	0	0	17	10	4	0	5	0	
3	1	0	0	0	1	5	1	0	4	many scales,coccinellids
4	1	0	0	0	0	0	4	1	0	" plus spiders
5	1	0	0	0	0	0	1	4	0	"
6	1	2	10	0	0	0	0	2	1	"
7	1	0	0	0	0	0	0	0	0	scales insects, wasps,flies
8	1	0	0	0	0	0	0	0	0	"
9	2	0	0	0	0	0	0	0	0	"
10	2	0	0	0	0	0	0	0	0	"
11	2	1	12	0	0	0	0	0	1	"
12	2	0	1	0	0	0	0	0	0	moulds on the egg slits
13	2	0	17	0	0	0	0	0	1	
14	1	0	0	0	0	0	0	0	0	
15	1	0	0	0	0	0	0	0	0	
16	2	0	0	4	2	0	0	0	0	
17	1	0	0	2	1	1	0	0	0	
18	1	0	0	0	1	0	1	0	0	
19	1	0	0	0	0	0	0	0	1	
20	1	0	0	0	0	0	0	0	0	
21	1	0	0	0	0	0	0	0	0	
22	1	0	0	0	0	0	0	0	0	
23	1	0	0	0	0	0	0	0	0	

APPENDIX B5

Species *Eurymeloides punctata*										
Plot no.- 1SA Trial										
Tree no.- 8G										
Treatment- ant-access										
Year- 2 (9 Nov 1987-18 Apr 1988)										
Week	no. of obs.	egg rings	egg slits	1st	2nd	3rd	4th	5th	adults	other observations
1	1	0	0	0	0	0	10	35	1	
2	1	0	1	0	0	0	1	25	12	
3	1	3	20	0	0	0	0	1	30	
4	1	7	104	0	0	0	0	0	12	
5	1	8	50	0	0	0	0	0	3	
6	1	1	8	0	0	0	0	0	2	wasps on the egg slits
7	1	1	10	62	18	0	0	0	1	
8	1	3	20	50	25	55	16	0	2	
9	2	1	18	19.5	20	19	45.5	11	1	few scales, shield bugs; robber flies; coccinellids
10	2	0	0	1	0	4	13	33	3	coccinellids
11	2	0	0	5	0	0	4	3	10.5	spiders; shield bug nymphs
12	2	0	0	2.5	4	5.5	0	1	3.5	shield bugs; a few scales
13	2	0	4	0	2	8.5	3.5	0	2.5	spiders; scales
14	1	0	0	0	0	3	5	3	0	
15	1	0	0	0	0	0	3	8	0	
16	2	0	0	0	0	0	1	8	1	
17	1	0	0	0	0	0	0	2	2	
18	1	0	0	0	0	0	0	0	1	many scales
19	1	0	0	0	0	0	0	0	0	
20	1	0	0	0	0	0	0	0	0	
21	1	0	0	0	0	0	0	0	0	
22	1	0	0	0	0	0	0	0	0	
23	1	0	0	0	0	0	0	0	0	

Species- *Eurymeloides punctata*
Plot no.- 1SA Trial
Tree no.- 7A
Treatment- ant-access
Year 2 (9 Nov 1987- 18 Apr 1988)

week	no. of obs.	egg rings	egg slits	1st	2nd	3rd	4th	5th	adults	other observations
1	1	0	5	0	0	0	0	0	1	
2	1	1	13	0	0	0	0	0	0	
3	1	2	24	0	0	0	0	0	2	
4	1	0	0	0	0	0	0	0	2	
5	1	0	0	12	0	0	0	0	2	
6	1	5	68	0	0	0	0	0	1	spiders
7	1	0	0	2	0	0	0	0	1	
8	1	0	0	24	4	0	0	0	0	
9	2	0	0	15	6	3.5	0	0	0	
10	2	0	7	0	3.5	7.5	7.5	1.5	0	spider
11	2	0	0	3.5	0	1	6	5	1	
12	2	0	0	3.5	0	1.5	2.5	5.5	5	
13	2	0	5	0	0	1	0	0.5	4.5	many scale insects
14	1	0	0	5	0	0	0	1	0	"
15	1	0	0	0	0	0	0	1	0	"
16	2	0	0	0	0	0	0	1	0	"
17	1	0	0	0	0	0	0	0	0	"
18	1	0	0	0	0	0	0	0	0	"
19	1	0	0	0	0	0	0	0	0	"
20	1	0	0	0	0	0	0	0	0	"
21	1	0	0	0	0	0	0	0	0	"
22	1	0	0	0	0	0	0	0	0	"
23	1	0	0	0	0	0	0	0	0	"

APPENDIX B7

Species-*Eurymeloides punctata*
Plot no.-1SA New
Tree no.- 1G
Treatment - ant-access
Year- 2 (9 Nov 1987-18 Apr 1988)

week	no. of obs.	egg rings	egg slits	1st	2nd	3rd	4th	5th	adults	other observations
1	1	0	0	20	0	3	4	40	3	
2	1	0	0	30	7	3	5	19	33	
3	1	2	20	20	15	8	5	5	20	
4	1	3	32	12	9	13	9	0	12	
5	1	1	10	5	8	9	7	4	6	
6	1	2	14	2	1	2	5	8	7	
7	1	1	9	44	0	5	4	11	7	
8	1	1	17	4	3	1	1	0	1	spider
9	2	1	8	9	5.5	5.5	2	0.5	4.5	
10	2	0	0	7.5	4.5	1	2	2	1	coccinellid adults and larvae
11	2	0	0	5.5	0.5	1	0	1	0.5	"
12	2	0	4	1	2.5	1	1	1	2	"
13	2	0	15	0	0	0.5	1	2	2.5	"
14	1	0	23	0	0	0	1	1	1	"
15	1	0	0	0	0	0	0	0	2	"
16	2	0	0	0	0	0	0	0	0	"
17	1	0	0	0	0	0	0	0	0	
18	1	0	0	0	0	0	0	0	0	
19	1	0	0	0	0	0	0	0	0	
20	1	0	0	0	0	0	0	0	0	
21	1	0	0	0	0	0	0	0	0	
22	1	0	0	0	0	0	0	0	0	
23	1	0	0	0	0	0	0	0	0	

Species	*Eurymeloides punctata*									
Plot n	1SA Trial									
Tree n	1C									
Treatment- ant-excluded										
Year-2 (9 Nov1987-Apr 1988)										
week	no. of obs.	egg rings	egg slits	1st	2nd	3rd	4th	5th	adults	other observations
1	1	0	0	40	25	0	0	0	1	
2	1	12	120	60	45	25	0	1	0	
3	1	0	0	0	10	25	45	8	0	
4	1	0	8	0	3	5	17	34	0	spiders
5	1	0	0	0	0	5	14	50	5	wasps on new egg slits
6	1	3	20	0	0	0	3	20	18	
7	1	2	16	0	0	0	0	0	7	
8	1	0	0	0	0	0	0	1	2	
9	2	0	0	0	0	0	0	0	0	
10	2	0	0	0	0	0	0	0	0	
11	2	0	0	0	0	0	0	0	0	wasps on the eggs slits
12	2	0	0	0	0	0	0	0	0	
13	2	0	0	0	0	0	0	0	0	
14	1	0	0	0	0	0	0	0	0	
15	1	0	0	0	0	0	0	0	0	
16	2	0	0	0	0	0	0	0	0	
17	1	0	0	0	0	0	0	0	0	
18	1	0	0	0	0	0	0	0	0	
19	1	0	0	0	0	0	0	0	0	
20	1	0	0	0	0	0	0	0	0	
21	1	0	0	0	0	0	0	0	0	
22	1	0	0	0	0	0	0	0	0	
23	1	0	0	0	0	0	0	0	0	

APPENDIX B9

Species-*Eurymeloides punctata*										
Plot no.- 1SA Trial										
Tree no.- 1G										
Treatment- ant-excluded										
Year-2 (9 Nov. 1987-18 Apr 1988)										
Week	no. of obs.	egg rings	egg slits	1st ins	2nd ins	3rd ins	4th ins	5th ins	adults	other observations
1	1	0	0	8	7	2	16	4	0	
2	1	0	0	15	10	5	4	30	0	
3	1	0	0	0	0	1	2	1	5	
4	1	0	0	0	0	0	2	2	4	
5	1	0	0	0	0	0	0	1	2	coccinellid adults
6	1	0	0	0	0	0	0	0	3	coccinellid ad + spiders
7	1	0	0	0	0	0	0	0	0	coccinellid larv., hailstorm+rain last night
8	1	0	0	0	0	0	0	0	0	
9	2	0	0	0	0	0	0	0	0	
10	2	0	0	0	0	0	0	0	0	
11	2	0	0	0	0	0	0	0	0	
12	2	0	0	0	0	0	0	0	0	coccinellid larvae
13	2	0	0	0	0	0	0	0	0	
14	1	0	0	0	0	0	0	0	0	coccinel. larvae+shield bugs(nymphs, eggs)
15	1	0	0	0	0	0	0	0	0	
16	2	0	0	0	0	0	0	0	0	
17	1	0	0	0	0	0	0	0	0	
18	1	0	0	0	0	0	0	0	0	
19	1	0	0	0	0	0	0	0	0	
20	1	0	0	0	0	0	0	0	0	
21	1	0	0	0	0	0	0	0	0	
22	1	0	0	0	0	0	0	0	0	
23	1	0	0	0	0	0	0	0	0	a few scale insects

Species- *Eurymeloides punctata*
Plot no-1SATrial
Tree no-8B
Treatment- ant-excluded
Year-2 (9 Nov 1987-18 Apr 1988)

week	no. of obs.	egg rings	egg slits	1st	2nd	3rd	4th	5th	adults	other observations
1	1	0	0	52	15	0	0	0	0	
2	1	4	70	40	40	15	0	0	0	spiders,feeding on 2nd ins.
3	1	0	0	20	25	30	35	10	0	
4	1	1	10	5	11	25	45	21	2	spiders
5	1	0	0	0	0	18	33	46	3	
6	1	0	0	0	0	0	3	18	5	
7	1	2	13	0	0	0	0	5	6	a few scale insects
8	1	1	4	0	0	0	0	0	2	"
9	2	3	23	0	0	0	0	0	0	"
10	2	0	0	0	0	0	0	0	0	"
11	2	0	0	0	0	0	0	0	0	"
12	2	0	11	0	0	0	0	0	1	"
13	2	0	0	0	0	0	0	0	0	wasps on egg slits
14	1	0	0	0	0	0	0	0	0	
15	1	0	0	0	0	0	0	0	0	
16	2	0	0	0	0	0	0	0	0	"
17	1	0	0	0	0	0	0	0	0	
18	1	0	0	0	0	0	0	0	0	
19	1	0	0	0	0	0	0	0	0	
20	1	0	0	0	0	0	0	0	0	
21	1	0	0	0	0	0	0	0	0	
22	1	0	0	0	0	0	0	0	0	
23	1	0	0	0	0	0	0	0	0	

APPENDIX B11

Species *Eurymeloides punctata*										
Plot no.- 1SA Trial										
Tree no.- 2B										
Treatment- ant-excluded										
Year-2 (9 Nov 1987-18 Apr 1988)										
week	no. of obs.	egg rings	egg slits	1st	2nd	3rd	4th	5th	adults	other observations
1	1	0	0	0	5	22	5	12	0	
2	1	0	0	0	0	1	21	6	5	
3	1	0	0	0	0	0	0	13	5	spiders
4	1	0	0	0	0	0	0	8	11	
5	1	0	0	0	0	0	0	0	12	
6	1	1	7	0	0	0	0	0	0	
7	1	0	0	0	0	0	0	0	0	
8	1	0	0	0	0	0	0	0	0	
9	2	0	0	0	0	0	0	0	0	
10	2	0	0	0	0	0	0	0	0	a few coccinellid adults, a few scale insects
11	2	0	5	0	0	0	0	0	0	wasps on new slits,coccinellid ad. eating scales
12	2	0	0	0	0	0	0	0	0	
13	2	0	0	0	0	0	0	0	0	
14	1	0	0	0	0	0	0	0	0	
15	1	0	0	0	0	0	0	0	0	
16	2	0	0	0	0	0	0	0	0	
17	1	0	0	0	0	0	0	0	0	
18	1	0	0	0	0	0	0	0	0	
19	1	0	0	0	0	0	0	0	0	
20	1	0	0	0	0	0	0	0	0	
21	1	0	0	0	0	0	0	0	0	
22	1	0	0	0	0	0	0	0	0	
23	1	0	0	0	0	0	0	0	0	

Species: *Eurymeloides punctata*
Plot no.- 1SA Trial
Tree no.- 3A
Treatment- ant-excluded
Year-2 (9 Nov. 1987-18 Apr 1988)

week	no. of obs.	egg rings	egg slits	1st	2nd	3rd	4th	5th	adults	other observations
1	1	0	0	0	0	0	0	0	0	
2	1	0	0	0	0	0	0	0	1	
3	1	0	0	0	0	0	0	0	2	spiders
4	1	0	0	0	0	0	0	0	0	coccinellids
5	1	0	0	0	0	0	0	0	0	spiders
6	1	0	6	0	0	0	0	0	0	
7	1	0	0	0	0	0	0	0	1	shield bug(adult)
8	1	0	0	0	0	0	0	0	0	
9	2	0	0	0	0	0	0	0	0	
10	2	0	0	0	0	0	0	0	0	
11	2	0	5	0	0	0	0	0	0	
12	2	0	0	0	0	0	0	0	0	
13	2	0	0	0	0	0	0	0	0	
14	1	0	0	0	0	0	0	0	0	
15	1	0	0	0	0	0	0	0	0	
16	2	0	0	0	0	0	0	0	0	
17	1	0	0	0	0	0	0	0	0	
18	1	0	0	0	0	0	0	0	0	some scale insects
19	1	0	0	0	0	0	0	0	0	
20	1	0	0	0	0	0	0	0	0	
21	1	0	0	0	0	0	0	0	0	
22	1	0	0	0	0	0	0	0	0	
23	1	0	0	0	0	0	0	0	0	

Species- *Eurymeloides punctata*

Plot no 1SA New

Tree no 3A

Treatment- ant-excluded

Year-2 (9 Nov 1987-18 Apr 1988)

week	no. of obs.	egg rings	egg slits	1st	2nd	3rd	4th	5th	adults	other observations
1	1	0	0	0	0	30	95	4	1	
2	1	0	0	0	0	0	46	83	1	
3	1	0	0	0	0	0	0	60	48	
4	1	0	0	0	0	0	0	13	69	
5	1	1	14	0	0	0	0	0	38	ants on the tree (removed)
6	1	1	9	0	0	0	0	0	5	
7	1	1	11	0	0	0	0	0	1	a shield bug
8	1	4	42	11	0	0	0	0	0	few ants on the tree
9	2	0	0	6.5	1	0	0	0	0	
10	2	0	0	0.5	3.5	3	0.5	0	0	coccinellids adults
11	2	0	0	0	1	1.5	3.5	1.5	0	coccinellid adults
12	2	0	0	0	0	0	0	3	2	
13	2	1	8	0	0	0	0	1.5	3	
14	1	0	0	0	0	0	0	0	0	
15	1	0	0	0	0	0	0	0	0	
16	2	0	0	0	0	0	0	0	0	
17	1	0	0	0	0	0	0	0	0	
18	1	0	0	0	0	0	0	0	0	
19	1	0	0	0	0	0	0	0	0	
20	1	0	0	0	0	0	0	0	0	
21	1	0	0	0	0	0	0	0	0	
22	1	0	0	0	0	0	0	0	0	
23	1	0	0	0	0	0	0	0	0	

APPENDIX B14

Species-	*Eurymela distincta*										
Plot no.	1SA trial										
Tree no.	1B										
Treatme	ant-access										
Year- 2	(9 Nov 1987-18 Apr 1988)										
weeks	no. of obs.	egg rings	egg slits	1st	2nd	3rd	4th	5th	adults	parasitised nymphs	other observations
1	1	0	0	0	0	0	0	0	0		
2	1	3	16	0	0	0	0	0	1		
3	1	0	0	0	0	0	0	0	2		
4	1	0	0	0	0	0	0	0	3		
5	1	4	25	0	1	0	0	0	3		
6	1	2	10	0	0	0	0	0	0		
7	1	0	0	2	0	0	0	0	0		
8	1	0	0	62	2	0	0	0	0		
9	2	0	0	57	23.5	0.5	0	0	0		
10	2	0	0	0	34	51.5	0	0	0		dryinid wasps
11	2	0	0	0	0	34	38.5	0	0	4(4th),2(3rd),	dryinid wasps
12	2	0	0	0	0	3.5	40	8.5	0	9(4th), 1(5th)	
13	2	0	0	0	0	0	6.5	11.5	0	4(4th), 4(5th)	
14	1	0	0	0	0	0	0	6	0		
15	1	0	0	0	0	0	0	2	1		
16	2	0	0	0	0	0	0	0.5	2.5		
17	1	0	0	0	0	0	0	0	2		
18	1	0	0	0	0	0	0	0	0		
19	1	0	0	0	0	0	0	0	0		
20	1	0	0	0	0	0	0	0	0		
21	1	0	0	0	0	0	0	0	0		
22	1	0	0	0	0	0	0	0	0		
23	1	0	0	0	0	0	0	0	0		

APPENDIX B15

Species- *Eurymela distincta*
Plot no.- 1SA Trial
Tree no.- 3E
Treatment- ant-access
Year- 2 (9 Nov 1987 - 18 Apr 1988)

week	no. of obs.	egg rings	egg slits	1st	2nd	3rd	4th	5th	adults	other observations
1	1	0	0	0	0	0	0	0	0	
2	1	6	48	0	0	0	0	0	0	
3	1	0	0	0	0	0	0	0	0	
4	1	0	0	55	0	0	0	0	0	scale insects
5	1	1	7	65	8	0	0	0	1	wasps on new eggs, coccinellid larv., spiders
6	1	0	0	5	10	0	0	0	0	"
7	1	0	0	0	0	3	0	0	0	coccinellid larvae and adults
8	1	0	0	0	0	0	0	0	0	tree is covered with scale insects
9	2	0	0	0	0	0	0	0	0	
10	2	0	0	0	0	0	0	0	0	
11	2	0	0	0	0	0	0	0	0	
12	2	0	0	0	0	0	0	0	0	
13	2	0	0	0	0	0	0	0	0	
14	1	0	0	0	0	0	0	0	0	
15	1	0	0	0	0	0	0	0	0	
16	2	0	0	0	0	0	0	0	0	
17	1	0	0	0	0	0	0	0	0	
18	1	0	0	0	0	0	0	0	0	
19	1	0	0	0	0	0	0	0	0	
20	1	0	0	0	0	0	0	0	0	
21	1	0	0	0	0	0	0	0	0	
22	1	0	0	0	0	0	0	0	0	
23	1	0	0	0	0	0	0	0	0	

APPENDIX B16

Species: *Eurymela distincta*
Plot no.- 1SA Trial
Tree no.- 7A
Treatment- ant-access
Year- 2 (9 Nov 1987-18 Apr 1988)

Week	no. of obs.	egg rings	egg slits	1st	2nd	3rd	4th	5th	Adults	parasitised nymphs	other observations
1	1	0	0	0	0	0	0	0	0		
2	1	4	61	0	0	0	0	0	0		
3	1	0	0	105	0	0	0	0	2		
4	1	0	0	140	0	0	0	0	0		
5	1	0	0	135	56	0	0	0	0		
6	1	0	0	55	145	15	0	0	0		spiders
7	1	1	16	7	50	58	0	0	0		
8	1	0	0	25	8	30	5	0	0		
9	2	0	0	16	11	12.5	8.5	0	0	3(3rd)	a wasp holding 3rd ins;laying eggs?
10	2	0	0	1	8.5	12	10.5	1	0	2(4th)	spider
11	2	0	0	0	1	14.5	6.5	1	0	1(4th),1(5th)	
12	2	0	0	0	0	4.5	7.5	1.5	0		
13	2	0	0	0	0	0	4	6	0		many scale insects
14	1	0	0	0	0	0	0	10	0		
15	1	0	0	0	0	0	0	8	1		
16	2	0	0	0	0	0	0	4	4.5		
17	1	0	0	0	0	0	0	0	7		
18	1	0	0	0	0	0	0	0	3		
19	1	0	0	0	0	0	0	0	2		
20	1	0	0	0	0	0	0	0	2		
21	1	0	0	0	0	0	0	0	0		
22	1	0	0	0	0	0	0	0	0		
23	1	0	0	0	0	0	0	0	0		

APPENDIX B17

Species-	*Eurymela distincta*									
Plot no.	1SA Trial									
Tree no.	1C									
Treatme	ant-excluded									
Year-2	(9 Nov. 1987-18 Apr 1988)									
week	no. of obs.	egg rings	egg slits	1st	2nd	3rd	4th	5th	adults	other observations
1	1	0	0	0	0	0	0	0	0	
2	1	2	10	0	0	0	0	0	1	
3	1	0	0	0	0	0	0	0	0	
4	1	0	0	0	0	0	0	0	0	spider
5	1	0	0	1	0	0	0	0	0	wasps on eggs slits, ants on tree
6	1	1	8	0	0	0	0	0	2	coccinellid ad. + larvae
7	1	0	0	0	0	0	0	0	0	
8	1	0	0	1	0	0	0	0	0	
9	2	0	0	0	0	0	0	0	0	
10	2	0	0	0	0	0	0	0	0	
11	2	0	0	0	0	0	0	0	0	
12	2	0	0	0	0	0	0	0	0	
13	2	0	0	0	0	0	0	0	0	
14	1	0	0	0	0	0	0	0	0	
15	1	0	0	0	0	0	0	0	0	
16	2	0	0	0	0	0	0	0	0	
17	1	0	0	0	0	0	0	0	0	
18	1	0	0	0	0	0	0	0	0	
19	1	0	0	0	0	0	0	0	0	
20	1	0	0	0	0	0	0	0	0	
21	1	0	0	0	0	0	0	0	0	
22	1	0	0	0	0	0	0	0	0	
23	1	0	0	0	0	0	0	0	0	

APPENDIX B18

Species- *Eurymela distincta*										
Plot no.- 1SA trial										
Tree no - 1G										
Treatment- ant-excluded										
Year- 2 (9 Nov 1987- 18 Apr 1988)										
week	no. of obs.	egg rings	egg slits	1st	2nd	3rd	4th	5th	adults	other observations
1	1	0	0	0	0	0	0	0	0	
2	1	11	75	0	0	0	0	0	0	
3	1	0	0	27	0	0	0	0	1	coccinellid adults
4	1	0	0	40	0	0	0	0	0	coccinellid ad + spiders
5	1	0	0	32	4	0	0	0	0	coccinel. larv., hailstorm+rained last night
6	1	0	0	0	0	0	0	0	0	
7	1	0	0	0	0	0	0	0	0	
8	1	0	0	0	0	0	0	0	0	
9	2	0	0	0	0	0	0	0	0	
10	2	0	0	0	0	0	0	0	0	coccinellid larvae
11	2	0	0	0	0	0	0	0	0	
12	2	0	0	0	0	0	0	0	0	coccinel. larv.+shield bugs(nymphs, eggs)
13	2	0	0	0	0	0	0	0	0	
14	1	0	0	0	0	0	0	0	0	
15	1	0	0	0	0	0	0	0	0	
16	1	0	0	0	0	0	0	0	0	
17	1	0	0	0	0	0	0	0	0	
18	1	0	0	0	0	0	0	0	0	
19	1	0	0	0	0	0	0	0	0	
20	1	0	0	0	0	0	0	0	0	
21	1	0	0	0	0	0	0	0	0	a few scale insects
22	1	0	0	0	0	0	0	0	0	
23	1	0	0	0	0	0	0	0	0	

APPENDIX B19

Species: *Eurymela distincta*
Plot no.- 1SA Trial
Tree no.-3A
Treatment- ant-excluded
Year- 2 (9 Nov 1987- 18 Apr 1988)

week	no. of obs.	egg rings	egg slits	1st	2nd	3rd	4th	5th	adults	parasitised nymphs	other observations
1	1	0	0	0	0	0	0	0	0		
2	1	8	70	0	0	0	0	0	0		
3	1	9	90	42	0	0	0	0	1		spiders
4	1	0	0	100	0	0	0	0	0		coccinellids
5	1	0	0	33	25	0	0	0	0		spiders
6	1	0	0	2	20	14	0	0	0		
7	1	0	0	0	0	10	6	0	0		shield bugs
8	1	0	0	1	0	1	12	0	0	1(3rd); 3(4th)	
9	2	0	0	0.5	0	1.5	4	1.5	0	2(3rd); 4(4th)	
10	2	0	0	0	0	0	0	1	0		
11	2	0	0	0	0	0	0	0	0		
12	2	0	0	0	0	0	0	0	0		
13	2	0	0	0	0	0	0	0	0		
14	1	0	0	0	0	0	0	0	0		
15	1	0	0	0	0	0	0	0	0		
16	2	0	0	0	0	0	0	0	0		
17	1	0	0	0	0	0	0	0	0		
18	1	0	0	0	0	0	0	0	0		some scale insects
19	1	0	0	0	0	0	0	0	0		
20	1	0	0	0	0	0	0	0	0		
21	1	0	0	0	0	0	0	0	0		
22	1	0	0	0	0	0	0	0	0		
23	1	0	0	0	0	0	0	0	0		